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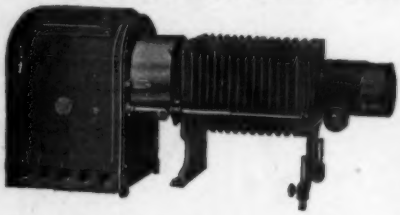

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SCHOOL SCIENCE AND MATHEMATICS

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THE DEVELOPMENT OF THE FUNCTION CONCEPT[1].

BY L. L. DINES,

Department of Mathematics, University of Saskatchewan.

The history of any science in its larger aspect is a record of the development of unifying principles. The biologist, not content with studying the isolated forms of life in the vegetable and animal world, has sought a unifying principle in the cellular organism which is common to all material life. The physicist in his search for a unifying principle in material structure has traveled a road marked by the signs molecule, atom, electron—and he is still going. In the investigation of forces, unification was begun by Newton, when he pronounced with such marvelous precision the law which governs the phenomena of gravitational attraction. Later developments have led to similar unification in the cases of electric and magnetic forces, and it requires no great stretch of the imagination to foresee the time when a single unifying principle will be pronounced as the basis for all physical forces.

Mathematics, as a pure science, deals not primarily with matter, with material life, or with forces, but with abstract classes of elements, and with relations existing between the various classes and elements. To be sure, the elements may be specialized to represent material objects, living organisms, forces, or any entities whatever. It is thus that mathematics, while being first of all an abstract science, is of universal application.

Does the abstract science of mathematics with its multitude of applications admit of any unifying principle? It would be bold indeed to offer any concept as ultimate. Such is certainly not my purpose. What I purpose is to develop, in so far as time will allow, a concept which, arising in a small and very special

[1]Read at the annual meeting of the Mathematical and Physical Society of Saskatchewan, April 2, 1918.

connection, has gradually expanded in significance until at present it seems, more than any other, to be serviceable as a unifying concept in mathematics.

The term function in a mathematical setting greets the present-day student probably for the first time in his study of trigonometry. He learns that associated with every angle there are six algebraic ratios, each with a name for which the teacher is obliged to offer an excuse more or less plausible; and that the six ratios are collectively called the trigonometric functions of the angle. Or the student may first meet the term function in his study of algebraic equations, when he is told that the left side of an equation such as

$$x^2+3x-2 = 0$$

may be abbreviated by the notation $f(x)$, to be read function of x.

Neither of these uses of the term comes first chronologically in the historical development. It is said that the term function was first used as a synonym of power. Thus a function of x would be equivalent to x^n. Evidently the use above mentioned in connection with algebraic equations is a direct generalization of this usage, and one which probably followed close upon the introduction of the term as synonymous with power.

From the application of the name function of x to a polynomial in x, it was evidently a short step to the extension of the term to represent any mathematical expression involving x, which furnished a formula by means of which when x was known the value of the function could be determined. The name seems first to have been used with this generalized formula significance by the famous Swiss Bernoulli brothers, John and James. Certainly the term function of a variable was first defined explicitly by John Bernoulli in 1718 as a quantity composed in any manner of this variable and of constants. In 1730 John Bernoulli took another distinctive step when he classified functions into two classes, algebraic and transcendental, according to the nature of the formula. The present-day functional notation $f(x)$, $\phi(x)$, etc., is due to D'Alembert and Euler, and was used first about 1754. The essential feature of the notion of function which we have so far developed is the existence of a formula which serves to determine the value of the function, when the value of the variable is known. The record of the development of the function concept thus far may be called the first chapter of its history.

From the earliest times the properties of geometric curves engaged the interest of mathematicians. Many of our simpler

curves were well known to the Greeks; for example, the circle, ellipse, parabola, hyperbola, and cycloid. The interest in these and other curves persisted through the period of mathematical stagnation which ended with the beginning of the seventeenth century. It was the great philosopher and mathematician Descartes who in the seventeenth century prepared the way for the union of our formula function concept and the concept of the geometric curve. His method of procedure is of course well known. With reference to a pair of fixed rectangular axes, he established a correspondence between the points of a plane and the totality of pairs of real numbers. To every point in the plane corresponds a unique pair of numbers (x, y), the coördinates of the point, and conversely to every pair of real numbers (x, y) there corresponds a unique point, the point of which these numbers are the coördinates.

The complete significance of Descartes' invention was of course not immediately grasped. It takes our present-day students at least a year to appreciate it, with the aid of what we hope are pedagogically correct methods of presentation. It was almost obvious, however, that in view of this invention the study of a geometric curve thought of as generated by a moving point was equivalent to the study of the simultaneous variation of the coordinates of a point which traversed it. And for most of the geometric curves then known, the ordinate y of a point traversing the curve could be expressed in terms of the abscissa x by means of a formula of a type then known; while on the other hand any formula $f(x)$ could be visualized by a graph, the locus of points whose coördinates satisfied the equation $y = f(x)$. It is of interest to note that this correlation of the formula function concept and the geometric curve concept took place before the name function had been attached to the former concept, at least by explicit definition.

Perhaps no other union of two distinct fields of any science ever did so much to enrich both fields. It is indeed difficult to say which profited more. Let me, however, point out a certain lack of reciprocity in the situation which was destined to lead to developments of tremendous significance. Given any formula function $f(x)$, the equation

$$y = f(x)$$

determined a curve, the locus of the variable point (x, y). By choosing arbitrary values of x as abscissas and computing from the formula the corresponding ordinates, any desired number of points could be plotted, and so the curve determined with an

accuracy limited only by the patience of the plotter. The existence of the locus which was being approximated was a logical certainty.

Consider now the converse problem. Given an arbitrary geometric curve; is there necessarily a function (formula) $f(x)$, such that the equation

$$y = f(x)$$

represents the dependence of the ordinate upon the abscissa? The question now before us came not from geometry but from the concept of physical law. Now the formulation of a physical law consists usually in the statement of the manner in which one measurable physical magnitude depends upon another. The fact of the dependence of one physical magnitude upon another is ascertained by experience. The general nature of the dependence is determined by repeated experiment and by induction. The question then arises: Can the dependence be expressed by a mathematical formula? This is the question which Newton answered in the case of the gravitational attraction between two material particles when he expressed its measure by the formula

$$\text{attraction} = c/x^2,$$

where c is a constant and x the distance between the particles.

Suppose now that it is desired to express by means of a formula the dependence of a physical quantity y upon a physical quantity x. Suppose that for a large number of values of x, the corresponding values of y have been determined (other factors being assumed constant), and that these correspondences have been represented by points in a Cartesian system. If then the physical quantities x and y are such that a gradual variation in x produces a gradual variation in y, it follows that the points which have been plotted are points of a continuous curve which represents the dependence of y upon x for all values of x. The next step is to formulate a relation

$$y = f(x)$$

which will represent this curve. It is not difficult to determine a function $f(x)$ which will correctly represent the correspondences for any finite number of points. This can, as a matter of fact, be done by means of a simple polynomial $f(x)$ whose degree is equal to the number of correspondences to be represented. However, for the vigorous mathematical physicist of the past two centuries, this is not a sufficient solution. He says: If x is a quantity susceptible of continuous variation, then no matter

how many correspondences of y and x you determine and comprehend in your formula, there still remains infinitely many more correspondences not considered. While our intuition tells us, and we are inclined to believe it, that if our formula is constructed so as to give correctly the value of y for a large number of values of x, it will then give y with close approximation for all values of x, we would like to have a definite "yes" or "no" answer as to whether there is a mathematical formula which will represent the correspondence between y and x accurately for all values of x at least within a finite interval. This question was first encountered by John Bernoulli in connection with the problem of the vibrating string.

Consider an elastic string, for instance a violin string, fastened at both ends. If it is initially distorted and then released, it will vibrate in the plane of its initial position. Bernoulli showed that an equation representing the form of the string at any instant of time t could be obtained if it was possible to represent by an equation, $y = f(x)$ of a certain type the form of the string at the initial instant of distortion. And then he showed that this latter representation was possible. There were, however, certain defects in Bernoulli's work and the most serious fault of all was the one of omission, in that he failed altogether to see the great import of his work. What he had really done when his problem was stripped of its physical setting was to show that any arbitrary continuous curve could be exactly represented by a formula. It was some years later, in 1812, that the French mathematician, Fourier, encountered the same question in a physical investigation. He was investigating the laws governing the conduction of heat, and he wished to express by means of a formula, temperature $= f(x)$, an arbitrary distribution of heat along a straight line. He found that whatever be the curve representing the temperature it could be represented by an equation of the form

$$y = a_0 + (a_1 \sin x + b_1 \cos x) + (a_2 \sin 2x + b_2 \cos 2x) + \ldots,$$

the function $f(x)$ being an infinite series of trigonometric functions. Since his time series of this type have been called Fourier Series, and have occupied an extremely important place in the developments of mathematical physics and of pure mathematics.

With Fourier, then, our function concept reached a stage in which it represented a correspondence between two simultaneously variable quantities, of a type which could be represented by the simultaneous variation of the ordinate and abscissa of an

arbitrary curve. The formula concept was not lost but was extended by the introduction of Fourier Series, so as to include this geometric concept. We may consider this as closing the second chapter of the history of the function concept.

The third stage of the development of the function concept begins with the work of Dirichlet in the first half of the nineteenth century. He was engaged in perfecting the work of Fourier on the representation of a function by means of a series whose terms were trigonometric functions. His work was of a kind more vigorous and critical than that of his predecessors, and he sought to make precise by an explicit definition what he meant by the term function of a variable. I will give the definition, not in the exact form in which it was given by Dirichlet, but in a form slightly more general, which is, however, usually associated with the name of Dirichlet.

Dirichlet's Definition of a Function: Let a and b be two fixed real numbers, and x a variable which gradually assumes all values between a and b. If y is a second variable whose value depends upon the value of x in such a way that to every value of x between a and b there corresponds a definite value of y, then y is said to be a function of x on the interval a to b.

How is this definition related to the two which we have previously considered? In the first place, nothing is said about the existence of a formula. If the dependence of y upon x in the interval a to b is expressible by means of an equation $y = f(x)$, where $f(x)$ is a formula, then y is a function of x in the Bernoulli sense. That is, the Bernoulli formula function concept is included in the Dirichlet definition. Likewise, nothing is said about the correspondence between y and x being representable by means of a curve. If, however, it is thus representable, then y is a function of x in the Fourier geometric curve sense. That is, the Dirichlet definition also includes the arbitrary geometric curve function concept. It is instructive to note some examples of functions in the Dirichlet sense which would not be included under the earlier definitions. For definiteness let the fixed numbers a and b be given by $a = 1, b = 4$.

First example: For any value of x, let y be the smallest integer greater than x.

Second example: When x is rational, let y be 1; when x is irrational, let y be $1/2$.

The peculiarities of these functions are best seen if one attempts to construct their graphs. For the first example, the

graph consists of a sequence of parts of straight lines, each having a definite left extremity but no definite right extremity. For the second example the graph consists of two sets of points, one on the line $y = 1$, the other on the line $y = 1/2$. Each set contains an unlimited number of points. Furthermore, if x increases gradually from any initial value, by any amount however small, the point of which x is the abscissa oscillates an unlimited number of times between the two lines.

The consideration of functions presenting such novel characteristics has received a great deal of attention during the last half century. Persons who are unsympathetic with the critical tendency of modern mathematics are apt to look with disfavor upon such investigations. It cannot be insisted too strongly that such a view is unwarranted and unjust. These investigations have contributed very greatly to the building of the powerful machinery of modern analysis. In particular, our real number system was evolved from an unsatisfactory condition admitting contradictions and paradoxes to its present state of consistency and efficiency by just such considerations on the part of the mathematicians Dedekind and Cantor.

We now come to the latest extension of the function concept, a precise formulation of which is a product of the last ten years, though the essence of the idea is much older. I warn you in advance that it is abstract. But I also remind you that it is the abstractness of mathematics which makes it of universal application. I will also endeavor to forestall possible adverse criticism by stating in advance that this generalization has already justified itself by unifying fields previously considered distinct, thus mutually enriching them as did the discovery of Descartes in the seventeenth century. Let me also encourage you by saying that it is quite as simple as the idea of Descartes. It is nothing more nor less than the Dirichlet definition generalized by the removal of the restriction that x and y must represent real numbers. To get the thing before us clearly, I first define what we shall mean by a variable, and then define the expression function of a variable.

Definition of Variable: A variable is simply a symbol, say p, which in a given discussion may be used to denote any one of a given set of objects. The set of objects, any one of which may be represented by p, is called the *range* of the variable p.

Definition of Function of a Variable: If p is a variable whose range is a class of objects P, and q is a second variable whose

range is a class of objects Q, and if the variable q is so related to the variable p that when p is given a definite value on the range P, q has a definite value on the range Q, then q is said to be a function of p, or more explicitly, a function on the range P, to the range Q. We may express the functional relation notationally by the equation

$$q = f(p).$$

If in particular the range P of p is the class of real numbers between two limits a and b, and the range Q of q is the class of real numbers, this definition reduces to that of Dirichlet. The generality of our present definition lies solely in the generality of the ranges of the two variables.

Let us see what are some of the functions relative to ranges other than the class of real numbers which have appeared as important in various branches of mathematics.

First Example:

P = [all complex numbers],

Q = [all complex numbers].

The study of functions $q = f(p)$ relative to these ranges constitutes the theory of functions of a complex variable.

Second Example:

P = [all *points* in a closed region of a plane],

Q = [all real numbers].

A function $q = f(p)$ relative to these ranges is sometimes called a numerical function of a point. Such functions are most common in mathematical physics, the numerical function representing for example the temperature at a variable point in a thin conductor, or the potential at a variable point in a plane field of force. Since the points in a plane can be put into one-to-one correspondence with the pairs of real numbers (x, y) by the method of Descartes, it is obvious that the study of the numerical functions of a point is logically equivalent to the study of the functions $z = f(x, y)$ of two real variables.

Third Example:

P = [all points in a closed region of a plane],

Q = [all *vectors* in a plane].

A function $q = f(p)$ relative to these ranges is sometimes called a vector function of a point. Such a function would represent for example the direction and rate of the flow of heat in a thin conductor, or the direction and intensity of the force active at any point in a plane field of force.

Fourth Example:

P = [all vectors in a plane and radiating from a fixed point],
Q = [all vectors in a plane].

A function $q = f(p)$ relative to these ranges is a vector function of a vector. The study of such functions is called *vector analysis.*

Fifth Example:

P = [a sequence of integers],
Q = [all real numbers].

Functions relative to these ranges are furnished by most tables of data. For example, suppose the range of p to be the sequence of days in a month numbered from 1 to 30, and the corresponding values of q to be the corresponding mean temperatures.

Sixth Example:

P = [all curves in a plane and joining two fixed points],
Q = [all real numbers].

A function $q = f(p)$ relative to these ranges is called a numerical function of a curve. One example of such a function would be the length of a curve. Since we have seen that every such curve can be represented by a formula function, the study of functions of a curve is logically equivalent to the study of numerical functions of a formula function. A small part of the theory of numerical functions of a variable curve, having to do with the maxima and minima of certain of these functions, has long been a subject of study under the name Calculus of Variations. It is only very recently (1913) that a work dealing with the general theory of functions of curves has appeared. It is by the eminent Italian mathematical physicist, Volterra.

Seventh Example:

P = [an absolutely arbitrary set of elements],
Q = [all real numbers].

The study of functions $q = f(p)$ relative to these ranges constitutes a branch of mathematics recently introduced by Professor E. H. Moore, and called General Analysis. It is of course very abstract, but for that reason its generality is great. It includes several of our earlier examples as special cases.

You will recall that my undertaking was to present a concept which to some extent at least forms a unifying concept for mathematics. Perhaps the numerous examples I have presented have persuaded you at least that the modern function concept is of very wide application. Before closing, I think it may be not without interest to examine those elementary branches of mathematics with which we are all as teachers or students of mathematics in vital contact, and to see if the function concept plays a fundamental role in them. I hope that in this investi-

gation I may not be misunderstood. I am not recommending the putting forward of this general and abstract concept as a pedagogical medium of instruction, at least in the elementary subjects; but I use these as familiar subjects for the testing as to whether the concept as a logical concept has a fundamental role in our mathematical structure as a whole. If it has, then the teacher should have the concept in the back of his head when he teaches algebra and geometry even though he brings it not out of his mouth.

Consider first algebra. Strip it of its applications, and look at the skeleton to see if we can discover a class of elements P, a class Q and a type of function $q = f(p)$ which is fundamental to algebra. I think we will all agree that the fundamental elements studied in algebra are numbers—let us say complex numbers. I now suggest for the classes P and Q:

P = [all *pairs* of complex numbers (a, b)],

Q = [all single complex numbers].

I then submit that the bulk of the logical structure of algebra is the study of the two functions

$q = f(p) = f(a, b) = a+b$,

$q = \phi(p) = \phi(a, b) = a \times b$.

There is a third function which plays a role, namely a function on the range

P' = [all pairs of numbers (a,n) of which a may be complex but n is a real rational number],

$q = \psi(p') = a^n$.

The logical skeleton of algebra is the study of the three functions f, ϕ, and ψ.

Next consider geometry. What are the elements studied in plane geometry? Perhaps we will agree they are points and lines. Can we think of any functional relation existing between these elements? Within the first few pages of almost any geometry text will appear the statement "Two points determine a line." This is a statement that there exists a function on the class of pairs of points to the class of lines. Let us then take

P = [all pairs of points (A, B) in the plane],

Q = [all lines in the plane],

and for the function on P to Q, take

$q = J(p) = J(AB)$ = junction line of A and B.

But we might equally well be guided by the statement "Two lines determine a point" (the point determined by two parallel lines being an ideal point at infinity), in which case our ranges would be

P = [all pairs of lines (a, b) in the plane],

Q = [all points in the plane (including ideal points at infinity)],

and

$q = J(p) = J(a, b)$ = junction point of a and b.

The study of this junction function, the range of whose variable consists of either pairs of points or pairs of lines, leads to that part of geometry known as the Geometry of Position or Projective Geometry. The interchangebility of the roles of points and lines in the functional relation leads to the beautiful theory of duality, which is so unhappily lost in our usual treatment of Euclidian geometry.

Much of the *Euclidian* geometry is based on a function relative to the range

Q' = [all real numbers],

the class P being either of the classes defined above. This function is

$q' = M(p) = M(AB)$ = measure of segment AB,

or $q' = M(p) = M(ab)$ = measure of angle ab

The part of geometry depending upon this measure function is sometimes called metric geometry.

The remaining subjects of our curriculum: trigonometry, analytic geometry, and calculus, require little comment. It will suffice to point out the ranges and the nature of the functions of which they treat.

Trigonometry: P = [all angles],

Q = [all real numbers].

Trigonometry studies six well defined functions on P to Q.

Analytic Geometry: P = [all points P in a plane],

Q = [all pairs of real numbers].

The analytic geometry differs from the geometry we have already considered in its dependence upon the functional relation of Descartes,

$q = f(p) = f(P) = (x, y)$ = the coördinates of P.

Calculus: P = [all real numbers],

Q = [all real numbers].

Elementary calculus may be defined as a method of investigating those functions

$$q = f(p)$$

which can be represented by formulas of certain simple types.

We have traced the development of the function concept from its unpretentious origin as a power of a variable to its present very general signification. I think we have verified by a sufficient

number of examples that to some extent at least it is a unifying concept. Is it indeed characteristic of mathematics? Many attempts have been made to answer the question "What is mathematics?" Two different types of definition have been attempted, one aiming to define the science by stating the *methods* used, the other aiming to define it by stating the kind of *material* studied. Few definitions of the first type excel for concentrated suggestiveness that of Benjamin Peirce in which he defined mathematics as "the science which draws necessary conclusions." I suggest for your consideration a definition of mathematics in terms of the kind of material studied as "the science which treats of functional relations."

PERIODIC DECIMAL FRACTIONS.

By M. O. Tripp,

University of Maine.

The object of this article is to show in a concrete way the relation existing between the number of digits in the period of a repetend and the theory of number congruences. An attempt has been made to explain this relation in such a way that the reader who has no previous knowledge of number theory may readily follow the discussion.

Let us start by taking a common fraction m/n, in which m *and* n *are positive integers relatively prime to each other. We assume that the denominator does not contain either the factor 2, or the factor 5;* for if 2 or 5, or both of them, were factors of n, we can multiply the fraction by 10^k, k being a properly chosen positive integer, and thus make the factor 2, or the factor 5. cancel from the denominator; then in our resulting decimal we may divide by 10^k, merely by moving the decimal point k places to the left, giving us a decimal equal to the original fraction. As a concrete illustration of the removal of such factors, let us consider the fraction 1/12. We multiply this fraction by 10^2, since 12 contains the factor 2^2. Therefore,

$$(1/12)10^2 = 8\ 1/3 = 8.333\ \ldots$$

Dividing 8.333 . . . by 10^2, we have

$$1/12 = .08333\ \ldots$$

In general, if $n = l\,2^a5^b$, we must take k, the exponent of 10, equal to the largest of the numbers a and b, or if $a = b$, k must be taken equal to their common value. If $l = 1$, that is, if the denominator contains only the factors 2 and 5, or either of them, then the fraction m/n is equal to a finite decimal.

Since the process of changing m/n into a decimal amounts to the multiplication of m by 10^k, then dividing by n, and finally dividing the result by 10^k by pointing off k decimal places; it follows that if n contains a factor other than 2 or 5, the division can never be exact, no matter what value k may take. *Hence, when n contains a factor other than 2 or 5 the decimal will be non-terminating.*

Two fractions m/n and r/n produce the same mantissa (purely decimal part) when, and only when, their difference is an integer, that is, when the difference between m and r is a multiple of n, or expressed in the language of number theory, when m is congruent to r with respect to the modulus n. We express this condition in symbols as:

$$m \equiv r(\text{mod}.n)$$

For example, 8/3 and 2/3 differ by an integer, and, therefore, we may write

$$8 \equiv 2(\text{mod}.3);$$

and, accordingly, the mantissae of 8/3 and 2/3 are the same.

Let us examine the question of the number of different mantissae existing for a given denominator n.

When $n = 3$, we have,

$1/3 = .333 \ldots,$
$2/3 = .666 \ldots.$

In general, we may say that in case the denominator is a prime number p, the number of possible mantissae is $p-1$.

If $n = 9$, we have,

$1/9 = .111 \ldots,$
$2/9 = .222 \ldots,$
$4/9 = .444 \ldots,$
$5/9 = .555 \ldots,$
$7/9 = .777 \ldots,$
$8/9 = .888 \ldots.$

We may now generalize by saying that in case the denominator is an integral power of a prime number, say p^n, the number of different mantissae is $p^n - p^{n-1}$.

As a third concrete case let us take $n = 21$, and hence we get

$$1/21 = .047619047619 \ldots.$$

As numerators, according to our conditions, we may take integers which are less than 21 and prime to 21, unity included. Hence the numerators may be 1, 2, 4, 5, 8, 10, 11, 13, 16, 17, 19, 20, thus giving us twelve different mantissae for the denominator 21.

In number theory, $\phi(n)$ is used to denote the number of positive integers less than n and relatively prime to n, unity included. The following relations are taken from the theory of numbers, and are stated without proof:

$$\phi(p) = p-1,$$
$$\phi(p^\alpha) = p^\alpha - p^{\alpha-1},$$
$$\phi(pq) = (p-1)(q-1),$$
$$\phi(p^\alpha q^\beta \ldots r^\gamma) = (p^\alpha q^\beta \ldots r^\gamma)(1-1/p)(1-1/q) \ldots (1-1/r),$$

$p, q \ldots r$ being different prime numbers, $\alpha, \beta, \ldots \gamma$ being positive integers. We, thus, have the general result: *There are $\phi(n)$ different mantissae for the same denominator n.*

We now take up the question of the periodicity of non-terminating decimals. The determination of the number of digits in the period by actual division is frequently a long process. The theory of number congruences, however, usually enables us to settle the question quite quickly.

If we multiply m/n by 10^k, the corresponding decimal will have the decimal point moved k places to the right. If k is so chosen that 10^k is equal to unity plus a multiple of n, then the mantissa will be the same as before, that is, m/n and $\dfrac{10^k-m}{n}$ will differ by an integer.

For example, let us take $1/23$ and determine the value of k so that the difference between $1/23$ and $10^k/23$ shall be an integer, that is, so as to make

$$10^k = 1+23l, (l = 1, 2, 3, \ldots).$$

Taking the various values of k, we find

$$10^1 = 10+0,$$
$$10^2 = 8+\text{a multiple of 23},$$
$$10^3 = 80+\text{a multiple of 23},$$
$$= 11+\text{a multiple of 23},$$
$$10^4 = 64+\text{a multiple of 23},$$
$$= -5+\text{a multiple of 23},$$
$$10^5 = -50+\text{a multiple of 23},$$
$$= -4+\text{a multiple of 23},$$
$$10^6 = 6+\text{a multiple of 23}.$$

Multiplying the last two equations together, we get

$$10^{11} = -1+\text{a multiple of 23},$$

and squaring this equation, we have

$$10^{22} = 1+\text{a multiple of 23}.$$

Hence $10^{22}/23$ and $^1/23$ differ by an integer, and therefore, their mantissae are the same. Thus

$$1/23 = .043478260869565217391\ldots,$$

and

$$10^{22}/23 = 43478260869565217391+\text{the mantissa of } 1/23.$$

Accordingly, to determine the number of digits in the period of a decimal generated by the fraction m/n, in the language of number theory, we merely determine the least value of k that will make

$$10^k \equiv 1 \pmod{n};$$

this value of k equals the number of digits in the period. It is thus evident that *the number of digits in the period depends upon n alone, and not upon the value of the numerator.*

In the theory of numbers, it is shown that k is always an exact divisor of $\phi(n)$. Thus, if we have a fraction whose denominator is 17, we find $\phi(17) = 16$, and, hence, the number of digits in the period must be 1, 2, 4, 8 or 16.

There are two kinds of periodic decimals: (1) *simple,* in which the period begins with the decimal point, such as

$$12/33 = .3636 \ldots,$$

(2) *mixed,* in which this is not the case, for example

$$13/14 = .9285714285714 \ldots.$$

The determination of the common fraction which generates a given periodic decimal may be made an interesting application of elementary algebra. Thus, if we let

$$x = .333 \ldots,$$

then

$$10x = 3.333 \ldots;$$

Subtracting

$$9x = 3;$$

Whence

$$x = 1/3.$$

Again, if we let

$$x = .363636 \ldots,$$

then

$$100x = 36.3636 \ldots;$$

Subtracting

$$99x = 36;$$

Whence

$$x = 36/99.$$

It should be noted that in each case we multiply x by 10 raised to a power equal to the number of digits in the period.

If the periodic decimal is mixed, it can be made simple by multiplying by 10^k, k being properly chosen. Tannery, in his *Leçons d'Arithmétique,* states the following theorem, which results from these algebraic processes: "Every simple periodic decimal fraction, in which all the digits of the period are not 9's, admits a generating fraction of which the numerator is formed by the period, and the denominator is composed of as many 9's as there are digits in the period."

AN ELEMENTARY STUDY OF PHYSICAL UNITS.

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"In order to get the fundamental unit of time, mass, and length, we must multiply a unit of mass by a unit of length. For example, if we buy a certain thing and get a foot pound, this is known as the fundamental unit of time."

This was an answer in reply to the question why the units of mass, length and time are called fundamental units, and was one of a number no less absurd given by pupils of high school grade in a recent examination.

For several years, I have examined papers from about a thousand pupils annually, in which the proper use of units was a feature in the examination, and have found in many cases the crudest ideas, while in schools where the subject was well taught, the answers were a credit to both the teacher and pupil.

I have no reason to suppose that those whose examination papers came under my inspection showed less appreciation of the meaning and use of units than the average; and if so, our schools are lacking in the inculcation of that definiteness which is so important a feature of scientific education. Any teacher who is not aware that the pupil's mind is likely to be exceedingly hazy if not hopelessly befogged in this matter has probably been content if the proper numerical answer to the problem was given and has not insisted that the *unit of measurement* be also given. But what is the use of being able to apply any number of formulae if when the *figures* of the answer are obtained it is not known whether the answer is expressed in terms of watts or ohms, or of feet or hours?

It is with the hope that the suggestions I make may be of value to teachers that this article is written; and in the first place the teacher needs to realize two facts: first, that the subject of units is *difficult;* second, that the subject of units is *easy*. It is difficult if approached in an abstract manner; it is easy if taken up properly, in a concrete form, with constant application of common sense, frequent returns to general principles and abundant illustrations, especially if these illustrations are emphasized by *absurd* questions.

The very best beginning in the subject is, I believe, the asking of such absurd questions as, "How many feet old are you? How many years heavy are you? How many pounds tall are you?" These questions are at once seen to be nonsense; and the

pupil by a very few judicious questions will be brought to explain that we cannot measure age by feet or weight by years or height by pounds.

The idea of a unit is thus arrived at. Everything that is measured must be measured in *some* unit, and, furthermore, must be measured in the *right* unit. Occasionally the unit is not expressed, as for instance when a boy on being asked his age says he is twelve, since in this case there is no possibility of his meaning twelve days, or twelve weeks, or twelve months. When two units are involved *one* of these units is frequently left out. If butter is said to be sixty cents, one knows that sixty cents a pound is meant; if hay is said to be seventeen dollars, the quantity indicated, though not expressed, is a ton. In the case of potatoes and vegetables, unfortunately, the measure for approximately the same money value is now *pecks* where a few years ago it was *bushels*. Nothing, it is easily made plain to the pupil, can be measured without a unit to measure by and this unit, though sometimes understood, is commonly expressed.

The first illustration given will show that at least three different units of measurement are necessary. We must measure length in the proper units which may be inches, feet and miles, or meters and kilometers; we measure mass in pounds and tons or grams and kilograms; we measure time in seconds, weeks and years.

Length, mass and time are independent of each other; the unit of one cannot be derived from the unit of another; we can express pounds in terms of grams, but we cannot express pounds in terms of seconds. This the pupil can easily see and if he is then told that all *physical* measurements can be expressed in terms of one, two, or three of these units, he can understand why they are the *foundation* units, the fundamental units of physics.

The simplest combination of units is involved in velocity. Here again the asking of absurd questions is a very excellent method for getting at the units involved. Ask how many feet a pound, or how many tons an hour, or how many hours a mile a train moves; and the pupil will be prepared for the question how many miles an hour or how many feet a second and will see that velocity involves length and time, and involves them in a certain manner.

The unit of velocity, then, is unit length in unit time. Any unit of length may be used and any unit of time. For instance,

an inch in a century, or a mile in a second might be chosen as the unit of velocity. In physics the *common* English unit is a foot per second and the common French unit a centimeter per second. A name might be given to such a unit; a foot per second might be called a *velo*, but no special name is usually employed for the unit, since it is easy to speak of a foot per second.

It is not simple folly to elicit by questions that one can no more tell the mass of a ball by knowing how fast it moves than one can tell the name of the boy who threw it. Absurd illustrations such as this will bring out the fact that velocity involves length and time and these units alone.

While velocity involves length and time in the simplest possible manner, acceleration involves the same units in a somewhat more complicated way. If a body is moving at the rate of ten feet a second and some time after is moving at the rate of fifteen feet a second, it is gaining velocity, but the *rate* at at which it is gaining velocity—the acceleration—is greater if it takes only a minute to gain the five feet a second than if it takes an hour, and still greater if it takes only a second to gain that acceleration. The acceleration of five feet per second per hour is less than an acceleration of five feet per second per minute, and still less than five feet per second per second. Hence it is seen that acceleration involves time twice. It is just as inexact to speak of an acceleration of five feet a second as to speak of a velocity of five feet. In other words, it is just as necessary in acceleration to bring in time *twice* as it is in velocity to bring it in *once*. In that system of units in which unit velocity is a foot per second, the unit of acceleration is a foot per second per second. This unit has no name, just as the unit of velocity has no name.

Velocity and acceleration involve the units of length and time; density involves the units of length and mass. In this case, length is involved *three* times, unit density being unit mass contained in unit volume which is unit length cubed. In the French system unit density is the mass of one gram in a cubic centimeter, and water at 4°C. has this density; there is no substance known of which one pound occupies a cubic foot, or a cubic inch and no substance has a density of unity in the English system. The density of substance compared with that of water is the specific gravity and this is more commonly determined and is sometimes *called* the density. In the French system of units the number denoting the specific gravity is really the num-

ber for the density; in the English system it is not.

In the consideration of force, pupils will need illustrations of various kinds in order to enable them to see that unless there is acceleration there is no force acting; because, since friction is always with us, the natural tendency is to think that force is necessary to *keep* a body moving at the same rate. That force varies as mass is not so difficult an idea; it is easier to move a pound than a hundred weight; it is easier to push a small boy than a big man. But in time it ought to be quite clear that force involves both mass and acceleration and nothing else.

Unit force gives unit mass unit acceleration. In the English units, unit force gives to one pound an acceleration of one foot per second per second. This expression is so long that a special name is given to this unit of force which is called a *poundal*. But unless the pupils have something more tangible than a definition such as the above, they will have little conception of what is meant by a poundal. Our conception of force is most closely connected with some strain on the muscles. The force of a pound weight we recognize from lifting a pound in our hand. But a pound mass if allowed to fall gains a velocity of 32 feet a second in a second (therefore has an acceleration of 32 feet per second, per second) so that a pound *weight* is 32 poundals and a poundal is the weight of half an ounce, or half the weight of a letter which in pre-war times would go for two cents, but now, unfortunately, requires three cents postage.

The French unit of force gives an acceleration of one centimeter per second, per second to a gram and is called a dyne (from the Greek word for force). The *weight* of a gram is 980 dynes and so a dyne is about the weight of a milligram or approximately one-fiftieth the weight of a postage stamp.

The simplest conception of work is that given by lifting a weight; and the work done depends upon the weight lifted and the distance through which it is raised. The ordinary unit of work is the foot pound or the work of raising a pound one foot. Work, then, may be defined as the product of the force acting and the space through which it acts. Now the pound weight is not the unit force, but the poundal; and therefore unit work (in the foot pound second units) is the foot poundal, which is one thirty-second of the foot pound.

Corresponding to the foot pound is, in the French system, the gram centimeter, and corresponding to the foot poundal is the dyne centimeter. A special name is given to the dyne centi-

meter. It is called an erg (from the Greek word for work) and is the work which would be done in lifting the weight of one-fiftieth of a postage stamp a centimeter high. It would require a good many ergs of work to load a ton of hay upon a wagon.

Now in foot pounds or foot poundals we seem to be multiplying two units and it might be thought that we can no more multiply six feet by four pounds than we can add six feet and four pounds or than we can multiply six apples by four plums. This is true; and it is only in a conventional sense that we can multiply feet by pounds. What we are really getting at is how many pounds can be raised one foot, or what number of feet one pound can be raised by the work required to raise four pounds six feet. It is the same kind of convention as allows us to divide feet by seconds to arrive at velocity.

If units are understood up to this point there should be no further difficulty. Work which we have expressed in terms of force multiplied by length can be expressed in terms of mass and velocity; for there is merely an algebraic transformation in changing the one into the other.

Power is derived from work. It is work divided by time. Horsepower is expressed in foot pounds per second or per minute. The electrical unit, the watt, is just a special unit of power and it is not difficult to derive the units of electricity if the units we have discussed are fully understood. Lessons on units must be combined with many exercises, and calculations of time, distance, velocity and acceleration; for instance, what velocity must a shell have on leaving an anti-aircraft gun if it is to reach a height of three miles, or how long would it take a man to reach the ground if falling from that height?

All the ordinary formulae can be derived and may be used but the pupil should be taken back to first principles from time to time, and should not be allowed to use formulae unless it is certain that he thoroughly understands them. If he uses the formula $S = \frac{1}{2} at^2$ it must not be necessary to tell him that the acceleration is five feet per second per second; it should be sufficient to tell him that a body which is moving with a velocity of twenty feet a second at a given instant is moving with a velocity of a hundred and seventy feet a second half a minute later.

Such training involves the expenditure of time and a great deal of care on the part of the teacher; but definiteness of this kind is invaluable to those pupils who intend to carry on the study of physics to an advanced stag.

DETERMINATION OF THE REFRACTING ANGLE OF A PRISM, AND THE ANGLE OF MINIMUM DEVIATION.

By Charles H. Skinner,

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As is well known, the index of refraction of a transparent substance in the form of a triangular prism may be determined by means of the formula,

$$n = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}},$$

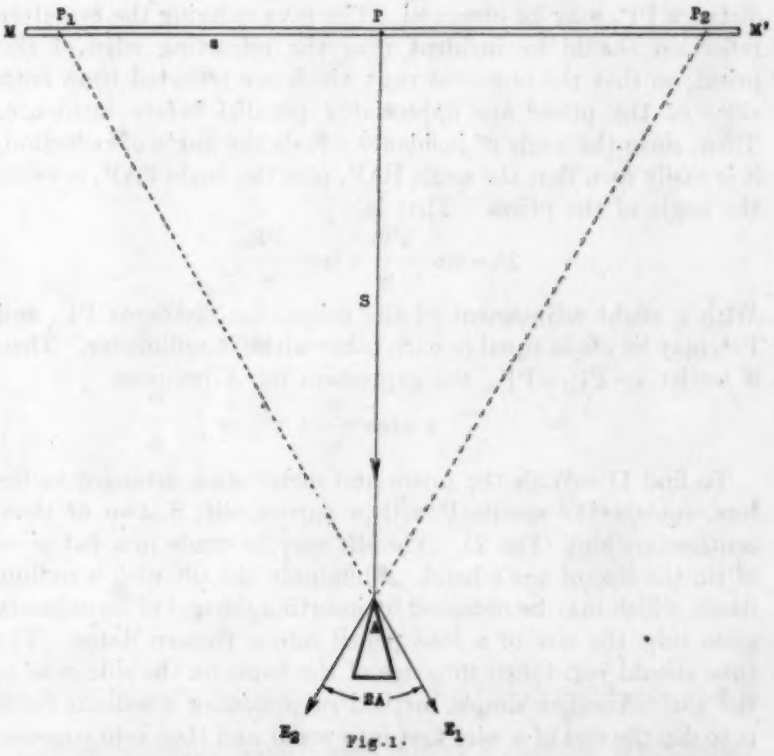


Fig. 1.

where A is the refracting angle of the prism and D the angle of minimum deviation. The laboratory experiment, as usually performed, necessitates the use of a spectrometer in measuring A and D. The following method has been designed to eliminate the spectrometer from the hands of beginning students, to substitute less expensive apparatus, and yet at the same time to furnish a precise method for the determination of A and D.

The apparatus consists essentially of the prism to be tested, two meter sticks, a fine sewing needle, and a narrow slit backed by a sodium flame.

To find A.—Lay a meter stick, MM′ (Fig. 1), edgewise on the laboratory table and fasten a needle at P, the middle of the stick, allowing the needle to project upwards. Place the prism on the table at a distance S from P, and with its refracting angle towards P. The prism should lie on a perpendicular to the stick erected at P. Then, placing the eye at some position, E_1, the reflected image of the needle may be seen at P_1, and the distance PP_1 may be read directly. Now, with the eye at E_2, the reflected image of the needle will be seen at P_2, and the distance PP_2 may be observed. The rays entering the eye after reflection should be incident near the refracting edge of the prism, so that the observed rays which are reflected from both sides of the prism are appreciably parallel before incidence. Then, since the angle of incidence equals the angle of reflection, it is easily seen that the angle PAP_1 plus the angle PAP_2 is twice the angle of the prism. That is,

$$2A = \tan^{-1}\frac{PP_1}{S} + \tan^{-1}\frac{PP_2}{S}.$$

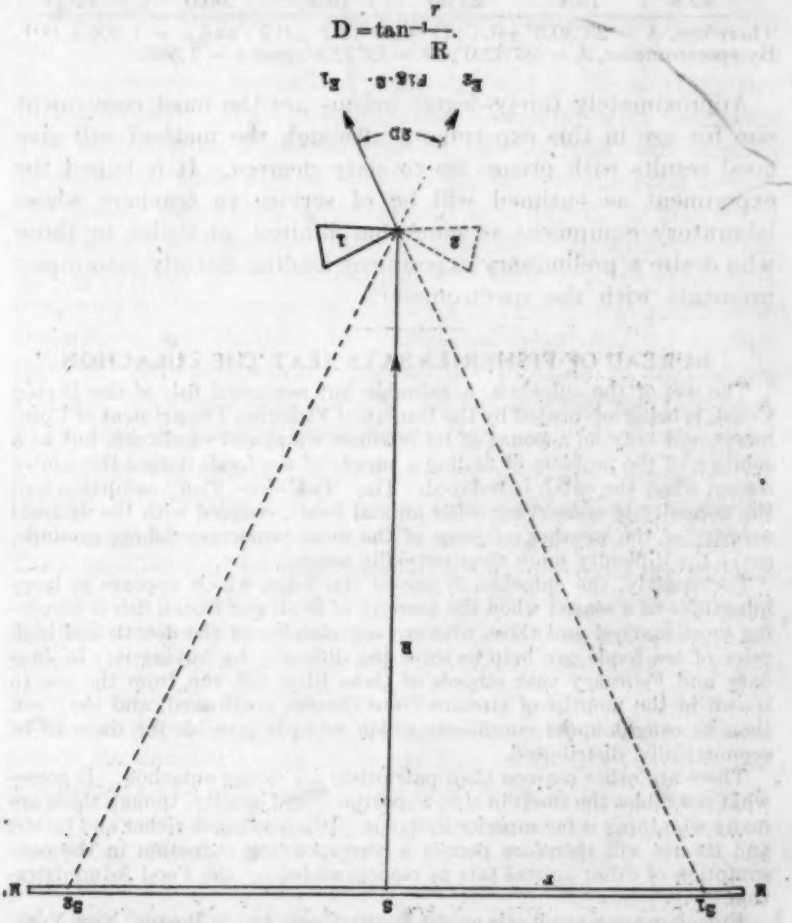
With a slight adjustment of the prism, the distances PP_1 and PP_2 may be made equal to each other within a millimeter. Then if we let $s = PP_1 = PP_2$, the expression for A becomes

$$A = \tan^{-1}\frac{s}{S}.$$

To find D.—With the prism and meter stick arranged as before, replace the needle P with a narrow slit, S, two or three centimeters long (Fig. 2). The slit may be made in a flat piece of tin the size of one's hand. Illuminate the slit with a sodium flame, which may be obtained by inserting the end of an ordinary glass tube the size of a lead pencil into a Bunsen flame. The tube should just touch the edge of the flame on the side next to the slit. Another simple method of obtaining a sodium flame is to dip the end of a wire first into water and then into common table salt, and hold this in the edge of a Bunsen flame. After illuminating the slit, turn the prism into position 1, and with the eye at E_1 observe the refracted image at S_1. The rays entering the eye after refraction should pass through the prism near the refracting edge. The position of the prism for the angle of minimum deviation is easily located by turning the prism slowly first one way and then the other. When this position is found,

observe the distance SS_1. Then rotate the prism into position 2, using the refracting edge as a pivot, and find the position of S_2 for the angle of minimum deviation. The distance SS_2 should be found equal to SS_1 within a millimeter. Call this distance r. Measure the distance R between the refracting edge of the prism and the meter stick at S. Then

$$D = \tan^{-1}\frac{r}{R}.$$



In the following table, three sets of values for determining A and D are shown, together with the values of A and D as determined by spectrometer measurements. A comparison of the results will at once show the precision with which the above method is capable.

It should be noticed that the value of n as determined by the above method checks within two-tenths of one per cent with the result obtained by the spectrometer.

To find A			To find D		
s (cms)	S (cms)	A (degrees)	r (cms)	R (cms)	D (degrees)
40.4	92.8	23°31′	22.4	103.5	12°12′
36.7	84.4	23°30′	21.5	99.0	12°15′
32.8	75.4	23°30′	19.5	90.0	12°14′

Therefore, A = 23°30.3′ ±0.3′; D = 12°13.7′ ±0.7′; and n = 1.506 ±.001.
By spectrometer, A = 23°32.0′; D = 12°12.8′; and n = 1.505.

Approximately thirty-degree prisms are the most convenient size for use in this experiment, although the method will give good results with prisms up to sixty degrees. It is hoped the experiment as outlined will be of service to teachers whose laboratory equipment is somewhat limited, and also to those who desire a preliminary experiment leading directly into measurements with the spectrometer.

BUREAU OF FISHERIES SAYS "EAT THE EULACHON."

The use of the eulachon, a valuable but neglected fish of the Pacific Coast, is being advocated by the Bureau of Fisheries, Department of Commerce, not only on account of its intrinsic value and excellence, but as a solution of the problem of finding a supply of sea foods during the winter season when the catch is reduced. The "Eat More Fish" campaign and the necessity of conserving other animal foods, coupled with the unusual severity of the weather on some of the most important fishing grounds, make the difficulty more than normally acute.

Fortunately, the eulachon is one of the fishes which appears in large quantities at a season when the scarcity of fresh and frozen fish is becoming most marked and those who are complaining of the dearth and high price of sea foods can help to solve the difficulty by buying it. In January and February vast schools of these little fish run from the sea to spawn in the mouths of streams from Oregon northward, and they can then be caught under conditions which make it possible for them to be economically distributed.

There are other reasons than patriotism for eating eulachon. It somewhat resembles the smelt in size, appearance and quality, though there are many who think it far superior in flavor. It is also much richer and fatter, and its use will therefore permit a corresponding reduction in the consumption of other animal fats as recommended by the Food Administration.

Eulachon are now on sale on the Pacific Coast and in Boston, New York, Philadelphia, Washington, Chicago, St. Louis, and other large cities and many small communities east of the Rocky Mountains. It is incorrectly known in some places as "Columbia River Smelt," "Pacific Smelt," or "Western Smelt."

The Bureau invites the cooperation of fish dealers and the public in the promotion of the use of this fish and has issued display cards recommending it and circulars containing recipes will be supplied gratis on application to Division F, Bureau of Fisheries, Washington, D. C.

SUGGESTIONS FOR ARRANGING AND KEEPING UP WITH APPARATUS AND MATERIALS IN THE LABORATORY.

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For the most efficient work some system and order must be observed. These requisites eliminate a large amount of the waste in the laboratory. As high school science progresses and our schools become larger, there is more need for orderliness in the laboratory. But seldom does this end of the work receive due attention. Most teachers sooner or later work out some kind of plan from their own experiences and from visits to other laboratories, while at first they merely imitate the plan used in the schools where they were trained. It is difficult to give specific helps on this subject: How best to keep up with materials and apparatus in the laboratory, and how to have them in a neat and orderly arrangement. This is largely dependent upon the plan of the building, the particular room, and the teacher himself. In salesmanship one of the mottoes is, "Study the goods." This may be of use here. That is, study the text-book to be taught, catalogs, and descriptions in science magazines.

Early in the course the teacher may profitably devote a few periods in allowing the pupils to become acquainted with the laboratory, the system used, and the care of ordinary materials. Each pupil should be impressed with his responsibility to keep his own place clean and in order. This goes far toward keeping the whole laboratory in order. Instill into the pupils the realization that science is a systematic subject, and that care and arrangement are necessarily a part of the work. The earlier pupils are given the proper training in laboratory habits and the earlier the teacher learns to be vigilant at all times, the earlier will materials be maintained in an orderly condition. The pupils who are reviewing the subject may aid much in caring for the materials. Pupils should gain the habit of putting away everything after using it. Psychology teaches us that human nature seeks the level of its environment. Apparatus scattered everywhere leads to confusion and the disorganization of the class.

Each laboratory should be large enough to allow ample space around the tables for teacher and pupils to pass each other comfortably. If there should be more than one laboratory, they should be placed in one corner or at the end of a wing. In this way material used in common for several sciences may be easily and quickly had. In using the same room for teaching two or

more sciences, materials used in each should be so cared for that they will not inconvenience the other classes.

There should be suitable tables for at least chemistry and physics. These should have ample storage room, so that each pupil may have his own locker, and a key for which he has paid a small deposit. A tight waste box should be provided for each table. This may be made of sheet iron and painted with asphalt varnish.

The location of the cabinets depends upon the sources of light and heat in the room. Cabinets, especially those that hold chemicals, must not be placed in the sunlight as this will hasten the decomposition of many chemicals. Also they should be placed as far as possible from the source of heat. Cabinets seem to be almost indispensable. But if it is impossible to have them, a good substitute will be found in a number of shelves. These may be made by nailing strips (one inch by 3 inches) to the ends of boards, so that the strips will form the posts that support the shelves. Upon these shelves are placed a sufficient number of strong pasteboard boxes properly labeled. These should be uniform in color and design, and suitable in sizes.

Shelves at the windows will be found very useful, as will also shelves placed in various parts of the room where they will be convenient but not unsightly. The shelves at the windows may hold insect boxes, small glass jars serving as aquaria, and various other articles; and much work may be done here.

It is well to have a small table in each room upon which may be placed, before the class assembles, the materials needed for work during that period. The materials should be laid out by the teacher or some trustworthy pupil. Each may return his materials to the table himself. This table should never be used for anything else, in order that it may be ready for use at any time. Another good plan is to make out a list of materials needed for each experiment, which should contain besides the name of the article, its number, the corresponding shelf number and cabinet letter, and any other concise information as to where the material may be found. These may be referred to as, 200 D 5. One list should be given to each pupil, or one posted upon the bulletin board in the room. In this way pupils may find and put away materials without any further assistance from the instructor.

Materials that are being used constantly should be put in a conspicuous and convenient place, while others may be placed where they will be less conspicuous and convenient. Pictures,

samples, and the like may be kept upon the ledge above the blackboard or upon a narrow shelf. Charts should be kept in suitable cases. A good form consists of an upright case attached to the wall, and opening on the front and top. A series of small drawers in which the charts lie flat are more useful but take up more space. Chart racks which may be raised or lowered over the blackboard will take care also of many exhibits. These may be made of a single strip of light wood (one inch by three inches), supported by a cord passed through a gimlet hole in each end of the strip, and small pulleys placed on the ceiling. It may be suspended almost anywhere and dispensed with at any time.

A storeroom is a necessity in a large school. This room should communicate with the laboratory and the classroom, and should contain several shelves. It should be a separate, small, and well-closed room, in which supplies may be kept under lock and in which the teacher may prepare much of his work. If it is near the classroom, the setting up and removal of lecture apparatus will be greatly facilitated. If one teacher handles both chemistry and physics, the storeroom and one classroom may serve both; but the laboratories should be placed conveniently near these. In this storeroom there should be a supply of clean pasteboard boxes, jars, bottles, cans, paper and cloth bags, envelopes, and labels. As soon as a container is used it should be placed in its proper place in the cabinet, storeroom, or museum. Labels should be protected by paraffin. The paraffin may be dissolved in carbon tetrachloride, and then applied with a brush.

Some simple method of classification will be necessary; and a card index with location on shelf, record of cost, dealer, inventory, and other useful information will be found helpful. To get rid of useless material and to keep the rest clean and in order, is an important rule applying to the storeroom. It is better to have in the general stock large amounts of materials to be used, than small amounts of many kinds, excepting, of course, for special reasons. Materials and apparatus should be selected to correspond to a somewhat definite course that has been previously mapped out. Of course, changes will have to be made at different times, since science work cannot be presented in a stereotyped form. Laboratories, like libraries, are never complete, but must be replenished from time to time. Although one should always eliminate the unnecessary, nevertheless good illustrative material should be kept in the museum. If there is no museum, then such may be made the nucleus of one. It is well to read the

textbook and list as one is reading the apparatus required, and afterwards look up the same in catalogs. Material that is seldom used should be grouped together, while that which is used only by the instructor for demonstration purposes may form another group. A piece of apparatus that is in bad condition should not be placed with other material, but should be put where such damaged materials are kept until it is repaired. If everything is inspected and put in good condition before it is stored away, much time will be saved.

If the teacher's demonstration table is to be used as a supply table also, it can scarcely be too long. It should then be provided with drawers and lockers, and may hold such supplies as are being constantly used by the pupils. Two want lists, one for things that are almost gone and another for things that are entirely gone, will be found to be very helpful. Then, if things are kept in a neat and orderly arrangement and nothing is put away unless it is in good condition, the teacher will have very little trouble in keeping up with them.

If there is no separate room for the biological sciences, a number of shelves placed in the physics laboratory will be found very useful. Of course, these shelves should not be placed where they will be unsightly, or where they will interfere with the conveniences of the physics classes. If there are insufficient lockers to provide each pupil with one, then each should have his own instrument box containing scissors, forceps, scalpel, blow pipe, two needles mounted in handles, pins, hand lens, pipette, absorbent paper, vial of vaseline for the instruments, set of rules on the use of the microscope, and a dissecting pan. The boxes may have partitions so that things may be kept in order. Each box should be properly labeled with the name of pupil and the number corresponding to the place for the box on the shelf. One or more shelves placed where they will be convenient, may be used for holding these boxes. Thus pupils may get their boxes upon coming to class and deposit them upon leaving. Instruments must never be returned to the box before they are thoroughly cleaned and dried.

If each pupil has his own small aquarium and an insect box, these may be set upon a shelf or table used for that purpose alone. They should, of course, be properly labeled. Microscopes may be kept under bell jars or in a place as free from dust as is possible and upon numbered shelves. If there are more pupils than microscopes, the pupils may be divided into groups

and each group given a certain microscope to use. This will make it possible to trace the source of any damage more easily. The lenses of microscopes are made of soft glass and should be rubbed gently with soft cloth. They should be kept at as even temperature as possible to prevent cracking of the lenses.

Much of the work in biology should be done out of doors, where real love for nature is to be had, and where the broader relationship between plant and animal life may be discovered. As a result of this work out of doors pupils carry into the schoolroom a lot of material, of which much has been collected out of mere curiosity. Because of this, biological laboratories have been pronounced places for the collected trash of the pupils. But if this material is organized into teachable collections, as roots, stems, leaves, or flowers, it will eliminate much of this material. Much material may be kept dry to be soaked before it is used. This may be stored in envelopes loose, or pasted on cardboard, and arranged alphabetically in a filing box. Also, plants may be kept on the usual size of herbarium sheets, uniform with sheets of flowering plants. The small-sized ones, however, are more easily handled. Boxes may be used for such things as fungi which refuse to be flattened out. Plants that are to be mounted on herbarium sheets may be successfully dried by the use of newspapers over which is placed corrugated paper. This is more satisfactory than the ordinary blotter method, provided the plants are kept in the sun while they are being dried. Xylonite may be used instead of glass for those specimens that are to be mounted under glass. Xylonite is lighter than glass and is less liable to be damaged. Glycerine jelly may be used for mounting many specimens, after which they are placed between sheets of glass, or between xylonite and glass, or between two sheets of xylonite, and then bound with passe partout. There is an excellent *Farmers' Bulletin* 586, on "Collecting and Preserving Plant Material." In the *Literary Digest* of July 12, 1913, there is an excellent article on "How to Preserve Plants in Their Natural Beauty."

Zoology collections may be organized into type forms. For keeping live aquatic specimens, an aquarium is necessary. Battery jars are the cheapest forms of aquaria and it is a good plan to have several of these. An oak barrel sawed in half makes a fine aquarium for large water plants and for fish. Materials may be preserved in a five per cent solution of the forty per cent formaldehyde. If the specimen is large, the skin should be punc-

tured in several places to admit the solution. Later many specimens may be transferred to a two per cent solution. An animal, such as a crab or turtle, may be dried in the shade after it is taken from the five per cent solution in which it has been kept about ten days and to which has been added arsenic (As_2O_3) in the proportion of one ounce to one-half gallon of the liquid. Specimens that are to be used for laboratory work during the same year may be placed in bottles, in the bottoms of which has been placed a little formaldehyde solution, and covered with absorbent cotton saturated with the solution; and the bottles sealed. Specimens that are to be preserved permanently had better be transferred to alcohol, since formaldehyde will gradually dissolve the calcareous skeletons. *Farmers' Bulletin* 606 is an excellent bulletin on "Collecting and Preserving of Insects." *Bulletin* 67 of the U. S. National Museum, "Directions for Collecting and Preserving Insects," is also very good.

In the physics laboratory each pupil should provide himself with a metric ruler. The barometer and thermometer should hang in a convenient, roomy, and light place, but not in the direct sunlight. Shelves that are perfectly level should be provided for the balances where the balances will be free from corrosive gases, draughts, and sudden changes of temperature. It is well to place a strip of wood one-half inch thick around the edge of the shelf, in order to prevent the weights from rolling off and being lost. Material may be arranged according to experiments, or according to the grand divisions of mechanics, heat, light, sound, and electricity, and then as nearly as possible according to experiments under these divisions. Materials that are used for several experiments may be grouped according to kind; as rulers, scales, etc., and then the groups arranged in alphabetical order. Each article should bear the group number, and shelf or cabinet number, and the number of the shelf in the cabinet. These may then be placed upon shelves of the cabinet or in strong pasteboard boxes upon open shelves. The boxes, of course, should be properly labeled with necessary information.

In the chemistry laboratory breakage and waste frequently are the results of sensory and muscular inaccuracy. The pupil must form such habits of accuracy of manipulation as are necessary for this present course. Highly refined dexterity, of course, should not be expected. How to keep up with apparatus also involves the care of it, as without care it would soon be destroyed, and where it goeth no one knoweth. Early in the course pupils

should be taught the bending of glass tubing and the making of other materials that are necessary for the carrying on of their work. If possible, the pupils should be made to appreciate the value of the appartus that they are using. They should be taught how to heat test tubes, flasks, and other glassware properly, so that accidents to these things, to themselves, and to others may be avoided. Many pupils melt the bottoms out of test tubes and wonder at the cause. It is not profitable to teach pupils to place a steel clamp around the test tube or flask, or a ring around the beaker, as the conductivity of the metal may cause breakage that they are unable to explain. Hot glassware should never be brought in contact with a cold surface, a cold draught, or water.

Each pupil should be provided with the necessary individual material which he should keep in his own locker. Also, each should have a strong pasteboard box in which to keep stirring rods, L tubes, glass blow pipes, and glass connections. If the teacher keeps a list of the materials received by each pupil, he will be greatly aided in keeping up with individual apparatus. At the end of the term pupils may place their individual materials in some suitable place, such as a drawer in the teacher's demonstration table, where they may remain during vacation. This material may be left in sets, which are placed in uniform boxes, and a list of the needed articles for each kept; or the various articles may be grouped according to kind, and note made of the amount of each. Charge for material that is not returned. If pupils want more material during the term, they should pay for it at that time, or a note be made of same and paid for at the end of term. For every group of two pupils there should be a set of common reagent bottles, sulphuric, nitric, and hydrochloric acids and ammonium hydroxide. For every group of four pupils there should be a set of two reagent bottles, sodium hydroxide, or potassium hydroxide, and calcium hydroxide. If the reagent bottles of each set are numbered with the number of the table and the particular group, it will help to keep them in their places. These numbers may be either etched in the glass or paper labels placed upon them and then coated with paraffin. The ordinary rack for holding reagent bottles found in the chemistry laboratory should not be more than fifteen inches high, so that unnecessary material and dust may not accumulate there, and that the instructor may have an unobstructed view of the entire class at all times.

Chemicals may be arranged alphabetically under acids, oxides,

and salts. Or they may be grouped according to use, and then these various groups arranged alphabetically. A series of shelves arranged in the form of steps in the cabinet or upon the wall will be found very convenient for holding chemicals, and will also be found to be very economical of space. Some must be wide enough to hold the largest containers. When placed upon the wall they should in some way be protected from the dust. There should be nonorganic containers for chemicals that are liable to spontaneous combustion, as, for example, potassium permanganate, nitrite, chlorate, silver oxide, and sulphur. Glass stoppers should be kept greased with vaseline in many cases, if used, in order that they may not stick; as in sodium hydroxide. Many compounds, as magnesium sulphate and sodium carbonate, effloresce; others, as sodium hydroxide and potassium carbonate, deliquesce. Many, as ferrous sulphate, are affected by the absorption of oxygen from the air. Glycerine, sulphuric acid, and alcohol are hygroscopic. Silver salts and oxides should be kept in amber bottles, and better also in the dark. A few chemicals absorb chlorine. All of these should be kept in air-tight bottles. Corks may be made air-tight by soaking them in paraffin in a hot water bath. Often before chemicals reach the schools they have been taken from the containers originally designed for them. Liquid acids, especially nitric acid, as it decomposes in the presence of light, of course, are kept in glass-stoppered bottles in dark places. Chemicals once taken from containers should never be returned to them, unless the instructor so directs. Other materials and apparatus, such as the blast lamp, should be kept in a certain part of the cabinet or on a separate shelf. They may be arranged alphabetically, or according to size, and a catalogue made.

A manual training workbench and a kit of carpenter's tools will be found very useful in the laboratory. If the bench cannot be had, it may be dispensed with; but the tools seem almost a necessity. With tools at hand many pieces of apparatus may be repaired which otherwise would be thrown away.

Although it is possible to be fastidious, or to be careless, in the arrangement of the materials in the laboratory, either, or both, defeat the object of science. Therefore, the sanest plan is to find the proper mean between these extremes. The proper mean, without doubt, is to be systematic about all the essentials.

ECOLOGY.

By Margaret M. Reidy,

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In the modern teaching of biology the vital relations of plants and animals and their adaptations to habitat or environment are of prime importance. In order to survive, individuals must solve the problems of food and shelter. To solve these problems, plants and animals have developed various modifications or adaptations to meet the conditions around them. Hence we find means of defense or of protection developed to a greater or lesser degree in all animals. The armor in beetles is often so thick that the beetle passes uninjured through the digestive tract of other animals. Strong biting jaws or stings are developed in various insects. Some larvae have poisonous hairs; the saw-fly larva ejects a poisonous fluid. Strategy is resorted to by beetles which when disturbed drop off into the grass in an apparent faint.

Few animals can afford to be conspicuous, hence coloration is a most important factor. Everywhere we find examples of resemblance, flash colors, warning coloration, and mimicry. As a rule animals in their natural environment are inconspicuous and are found only by careful searching. The grasshoppers, praying mantis, walking sticks, and the larvae of many insects illustrate this form of protection.

Flash colors which are suddenly brought into view when the possessor takes flight and are tucked away again on alighting may enable species to keep together, but also help to bewilder the enemy (as illustrated by the underwing moths).

When insects have other means of protection as sting, secretions, bad odor, or bad taste, conspicuous or warning colors are developed. They are easily recognized and for the most part these insects are left alone. The most specialized of warning colors are eyespots (seen in owl beetle). These are generally remote from the true eyes, and upon some part of the body well exposed to the view of its enemy, and always large enough to belong to an animal many times the size of the one possessing them.

Mimicry of the color of insects which can afford to be conspicuous is noticeable in the many flies which resemble bees or wasps. The viceroy butterfly mimics the monarch and is credited with the bad taste and odor of the latter, and is thus protected.

Certain flies resemble ants which are distasteful on account of the formic acid they secrete.

Two products of flowers (nectar and pollen) are eagerly sought by insects. Here the interrelations are of mutual advantage. The insects secure food and in return serve the flower by transferring the pollen from the anther of one flower to the stigma of another, thus securing cross-pollination.

Flowers are variously modified in adaptation to these insect visitors. The bright colors attract. The nectar exhales a variety of scents, and the nectaries are sequestered in various ways beyond the reach of visitors which would take the nectar and not help in cross-pollination. Often the nectaries are hedged about with spines or glandular hairs, or are at the bottom of deep passageways, and thus reserved for the use of proper guests.

In the insect family, the corolla is two-lipped, with the lower serving as an alighting place and the upper as a shelter for the pollen. The stamens are often reduced to one or two pairs, and the anthers so situated that the insects rub against them at just the right time. Often the flowers are brought together in clusters; thus showiness is secured, and it is possible for the insect to pass from one flower to another without taking flight (Queen Ann's lace and dandelion).

Since insects visit the flowers for food, we find that the parts of their bodies which serve for collecting and carrying the nectar and pollen are the most modified for flower visitation. Only a few insects with biting mouth parts visit flowers. In these the front of the head is more or less narrowed, and stiff hairs appear in place of the usual teeth (soldier beetle of golden rod.).

Most nectar-eating insects have mouth parts prolonged and combined into a sucking tube, with which they are better able to reach the nectar. The honey bee has this tube hinged and retractile. The proboscis of moths and butterflies is the most specialized and is coiled like a watch spring beneath the head when not in use, and when unrolled sometimes exceeds the length of the body. Thus it is adapted for reaching the nectar in the deepest corollas and for entering the narrowest passageways.

The horny shell of the insect's body, if bare, would carry little pollen, but the brushes of hairs usually developed on top of the thorax, undersurface of the abdomen, and outer faces of

the legs carry the pollen grains excellently and implant them on the stigma.

The bee is beautifully adapted for getting into and out of specialized corollas, since the antennae are reversible, the legs closely applied to sides of the body, and the wings closely folded upon the back, making the whole insect compact.

Not only do we find plants and animals adapted to habitat and to each other, but we can find no plant or animal that will not show a community of life with relations infinitely varied and complex. One of the most interesting of these complex relations is found in the galls. These abnormal growths of plant tissue are occasioned by stimuli furnished by a variety of insects and a few parasitic fungi. Such overgrowth appears only if the irritation is applied while the tissue is rapidly developing. In animal galls, under this stimulus tissue grows rapidly, producing more food. Around the point of attack it grows and shuts in, covers and protects the gall makers. It continues to grow, and in its final form often resembles a fruit, and sometimes produces unpalatable substances in its walls and sharp spines on its surface, and thus protects its enemy, the gall maker, from being eaten.

The sumac is another splendid example of this community life. The fruiting heads are large and loosely arranged, affording food and shelter for many insects. The pith cavity is large and the wood soft, thus the stem furnishes a habitat for many forms of life. The carpenter bee is one of the most interesting of these. The bee finds an entrance through the end of a broken branch. She excavates the pith for some distance down the stem, then collects a quantity of pollen and places it in the lower part of the cavity, then lays an egg in the pollen and builds a partition across. This process is repeated until the tunnel is filled up. The bee remains at the opening until the eggs hatch out and emerge as adults. Food enough is stored in each cell to feed the larva until fully grown when all escape through the opening at the upper end. It is interesting to note that the first egg hatched is the last one to escape.

Another interesting relationship is seen in ants and aphids. The food of the aphids consists of sap which contains more sugar than the aphid is able to assimilate. This excess of sugar is discharged from the body in fluid drops of honeydew. Ants gather this honeydew from the leaves, and from gathering it at large this way they have passed to gathering it from the aphids themselves. We find them protecting aphids often building

shelters about the aphid colonies; probably in this way a larger and more constant supply of honeydew is secured. There is a permanent association of ants and aphids, in which the ants care for the eggs and help young aphids to favorable positions on roots of plants. These relations continue without cessation throughout the year.

These are but a few of the many adaptations present in the life about us. The problem is to awaken in the boy and girl of high school age, an interest in the vital relations of plants and animals and their adaptations to environment.

BOYLE'S LAW APPARATUS FOR THE LECTURE TABLE.

By C. R. Herrick,

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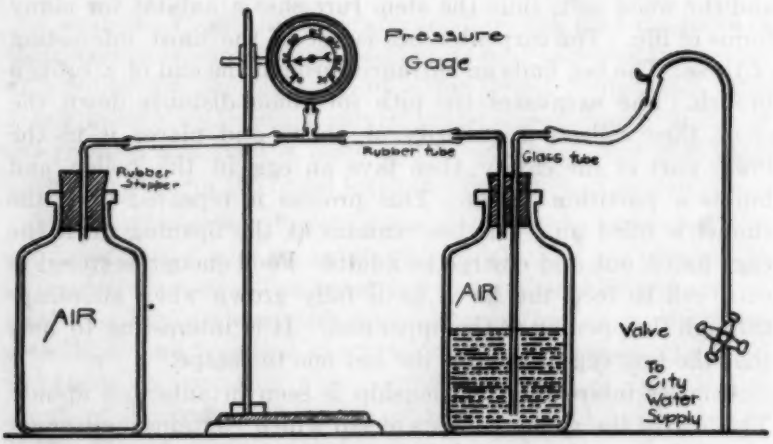
The various forms of apparatus commonly used to demonstrate Boyle's Law are generally not very convincing; at least, from the pupil's point of view. The use of mercury columns for pressure is not comprehended at once by the ordinary high school pupil. In some forms the change of volume is not really seen but only inferred. The apparatus here described can be set up from materials found in any laboratory. No mercury is used and the volume and pressure changes are strikingly clear.



The bottles shown in the diagram are the common acid bottles of 5 pint or 2500 c. c. capacity. Any two of these are nearly enough alike for the purpose of this experiment. The rubber tubing used for connections is ¼ inch inside diameter and of

double thickness. If only a few feet of this tubing are used the volume of air in the tubing is negligible. The pressure gauge may be the cheap type that can be purchased for about $1.50. Its range ought not to exceed 30 pounds. The gauge is connected between the bottles by means of a brass T tube of ¼ inch inside diameter.

After the apparatus is set up as illustrated, turn on the water from the city supply. Shut off the water when the first bottle is half full. Evidently the volume of air that originally filled the two bottles has been compressed to ¾ of its former size, therefore, by Boyle's Law, the pressure must be the inverse of ¾, namely ⁴/₃ of the original value.

Assuming atmospheric air to have 15 lbs. per sq. inch pressure, the pressure of the air in the bottles at this stage will be ⁴/₃ of 15 or 20 lbs. per sq. inch. As commercial gauges record only the pressure in excess of the atmosphere, the reading of the gauge will be 20-15 lbs., as shown in the diagram. Again turn on the water until the first bottle is just filled. The original volume of air has been reduced ½ and the pressure has consequently doubled, as proved by the gauge reading 15 lbs.

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In addition to the topographic surveys of a military character conducted by the United States Geological Survey, Department of the Interior, there has been an increased amount of confidential military data collected in the field by the Geological Survey geologists and hydraulic engineers. Much of this was contributed in connection with the progressive military work, but more detailed data were collected to answer specific inquiries as to water supply, structural materials, and oil and gas available at sites for camps, aviation fields, and munition plants. The special examinations of surface and underground water supplies increased in number and included both qualitative and quantitative studies, as well as investigations of problems of sewage disposal.—[From Annual Report of Director United States Geological Survey.

GENERAL SCIENCE IN MICHIGAN.

By Adrian A. Worun,
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The subject of general science has been discussed throughout the country for the past five or six years. Its aims, advantages, place in the curriculum, content and method have been the subject of articles in educational magazines; committee reports have been published on it and science conferences have considered it from all angles. Surveys of general science have been made in many states; this report is made so that the status of general science in Michigan may be known.

The data which are the basis of this report was received from answers to a questionnaire which was sent to the high school science instructors in the schools on the 1916 accredited list of the University of Michigan. Accredited schools were chosen because they, it is assumed, are representative of Michigan schools; and furthermore, they are the schools that are interested in University recognition for general science. As the questionnaires were answered in the fall of 1916, this report deals with the conditions of general science for the first semester of the school year 1916-17. One hundred and seventy-two of the two hundred and eighty-three schools on the list replied.

When answering the question, "Is a course in elementary or general science offered?" instructors were asked to distinguish between elementary and general science according to the distinction made by Prof. E. D. Huntington of the Western Normal of Michigan as given in his "Discussion of the Report on the Elementary Science Situation in Michigan," printed in the *Journal of the Michigan Schoolmasters' Club, 1916:*

"The essential difference between elementary and general science is that the former would present the elements of certain specialized sciences to the child from the standpoint of the sciences, while general science would select facts and principles from the whole field of science according to the needs of the ninth grade child and endeavor to present this subject matter to the child by such methods as will arouse and hold his interest."

In case neither such course was offered, the question was to be answered—neither. Below are the answers to the question quoted above together with the data received from the question, "If no general science course was at present offered, is it your plan to do so soon?"

Having elementary science	7 replies
Having general science	69 replies
Having neither	96 replies
Planning to offer it soon	36 replies

The distribution of schools according to high school enrollment furnishing the above data is given below:

Enrollment	Elementary	General	Soon	Neither
Under 100	2	14	10	40
100-200	4	30	18	32
200-300	1	13	4	8
300-400	--	4	2	7
400-500	--	2	1	4
500-600	--	1	---	---
600-700	--	2	---	---
700-800	--	---	1	1
800-900	--	---	---	---
900-1,000	--	---	---	1
Over 1,000	--	3	---	3

In order to facilitate discussion, elementary science will be considered under the head of general science during the remainder of this report.

Our data show that:

I. At least 27 per cent of the 283 accredited schools offer general science.

II. At least 22 per cent of the entire number of high schools in Michigan, 345 in number, offer general science.

III. One-half of the schools offering general science are in the North Central Association of Colleges and Secondary Schools.

IV. Assuming that the schools answering "soon" carry out their plans, in the near future, 112 or at least 39 per cent of the accredited schools will be offering the course. Three schools are offering the course for the first time during the second semester of the year 1916-17.

Two instructors volunteered the information that they were offering no such course "because the university does not recognize it." Five schools report that "we will offer it as soon as it is recognized."

The data from the questions, "In what grade is general science offered?" and "What is the length in years?" are tabulated below:

Grade	Length of Course	Occurrence
9	1 year	40 times
9	½ year	6 times
9-10	1 year	3 times
9-10	½ year	1 time
9-12	1 year	2 times
10	1 year	3 times
8- 9	1 year	3 times
8- 9	½ year	1 time

8	1 year	9 times
8	½ year	1 time
7- 8	2 years	4 times
7-8-9	3 years	3 times

The above table shows that, as regards to position in the curriculm:

21 courses are below the ninth grade.
59 courses are in the ninth grade.
9 courses are above the ninth grade.

Where the course is in the high school:

51 are 1 year courses.
8 are ½ year courses.

Where the course is below the high school:

15 are 1 year courses.
2 are ½ year courses.
4 are 2 year courses.
3 are 3 year courses.

In the above three tables, the courses that were offered both in the ninth grade and below were treated as separated courses, as were those appearing both in the ninth grade and above. This explains the discrepancy of more schools answering the question quoted above than the number, 76, that actually have the course.

Two schools, Scottville (enrollment 175) and Munising (enrollment 125), reported themselves as being on the 6-6 plan (six years elementary school and six years high school). The Scottville course in general science is arranged thus:

Grade 7—elective, reciting two forty-five periods per week.
Grade 8—elective, reciting three forty-five minute periods per week.

Munising reports:

Grade 8—compulsory, reciting five forty-five minute periods per week.

Kalamazoo reports six schools offering general science, three of these have a Junior High School of seventh, eighth and ninth grades and offering it in each grade. In these schools, the course is distributed thus:

Grade 7—required, reciting two forty-five minute periods per week.
Grade 8—elective, reciting four forty-five minute periods per week.
Grade 9—elective, reciting five forty-five minute periods per week.

In the other three schools, the course is distributed as in the seventh and eighth grades above.

Muskegon reports one five year high school. General science is offered in the eighth grade and is continued as organic physiology in the ninth, being compulsory in both grades.

Grand Rapids Central High School reports an elective course offered in 8b and 9a and continued in 9b as physiology, the course being one or three semesters in length.

The answers to the question, "What other sciences are taught in the school, and in what years?" taken from the schools that answered as having general science are tabulated below. Only high school subjects are considered.

Science	9	10	11	12	Total
General Science	57	9	2	2	70
Botany	18	32	1		51
Physiography	4	14	2	1	21
Zoology	1	13	1		15
Biology	5	11	1	1	18
Agriculture	2	8	13	7	30
Physiology	2	8			10
Physical Geography	3	4	1		8
Horticulture		1	1	1	3
Greenhouse and Garden Practice		1	1	1	3
Geology			1		1
Chemistry			54	17	71
Physics			17	54	75
Hygiene				2	2
No Course		5	1		6

In addition to the seventy courses of high school general science, there are two in the seventh grade and seventeen in the eighth grade.

The table should be read: General science is given in the ninth grade in fifty-seven schools, in the tenth grade in nine, etc.; similarly for other subjects. Many schools offer the same course during different years; such is the case with horticulture and greenhouse and garden practice; two schools offer agriculture in each of the high school years. Five offer it for three years and three for two years. The largest number of science courses offered in one year in any school is four. General science is the dominant subject in the ninth grade; botany in the tenth grade; chemistry in the eleventh grade; physics in the twelfth grade. There are as many twelfth grade chemistry courses as there are eleventh grade physics courses. The poor showing of physiography is due to the fact that it is superseded twenty-eight times by general science. We notice that general science ranks third in the high school science curriculum; ⅔ of ninth grade science courses are general science courses.

The aims and purposes for the course "that have been formulated in order to justify it to school constituencies and pupils" are divided as follows: The number following denotes the number of times it was mentioned—some instructors having more than one aim for the course:

I. General science lays the foundation for future science courses 47
Stimulates interest in science 15
Enables pupils to choose intelligently science courses in the future 8

	Embraces all science	1
	Teaches diction of science	1
	Introduces scientific methods	6
	Good introductory course to specialized science	11
	Shows interrelation between sciences	1
	Removes dread of later sciences	1
II.	General science explains the pupils' environment	31
	Pupils can understand interests in town that depend on science	4
	It gives an understanding of everyday phenomena	10
	Student can appreciate the beauties of nature	1
	Teaches everyday life	10
	Student will find that he can discover things for himself	1
	It is more practical than physiography	1
	Gives general information—is cultural	3
	Pupils will be able to understand scientific papers	1
III.	Those people who do not elect the specialized science courses later or who drop out of high school will nevertheless have some science	19
IV.	Unclassified aims	4
	It is so important that it should have a place	1
	The work is interesting	1
	It discovers whether student leans to science or not	1
	Keeps people in school	1

The dominant aims, then, of general science are to prepare for the specialized courses, and to explain environment; utilitarian, both of them. Many instructors made much of the third aim, one reporting that it convinced the school board in his city.

The answers received to the question, "What are the advantages of a course in general science?" show that advantages are along the same lines as the aims and purposes. One instructor replied, "The advantages are too numerous to mention," while another enthusiastically declared that there was not room on the paper to put them all down. Still another reports that general science is such a good foundation for later courses that there may have to be two sections in the later courses, one for the students who have had general science and another for those who have not had it. The advantages are classified below:

I.	It is a foundation for later courses	29
	Stimulates an interest in science	12
	Gives general knowledge in science	1
	Prepares people to choose science later	8
	Correlates science	2
	Introduces scientific methods	2
	Makes ground work for other science	1
	Introduces a scientific attitude of mind	1
	It makes a quick get-a-way in physics and chemistry	1
	It gives more advancement in higher courses	1
	It dispels the haze that attends the beginning of advanced courses	1
II.	It explains environment	10
	It explains everyday life	9
	Students who take it get an appreciation of nature	1
III.	Unclassified advantages	9
	It covers all the sciences at any time	1

It has big teaching values—social, intellectual, etc.	1
Most people have an interest in science at that age	1
It humanizes the curriculum	1
It teaches how to study	2
The course is popular	1
It keeps people in school	2

The fact stands out, that the great advantage of general science for the student is that it makes future science easy to him. But we cannot judge from the figures that he is prepared for future science twice as much as his environment is explained to him, for explanation of environment and preparation for future courses undoubtedly go hand in hand in most instances.

Any course which is new in a curriculum naturally has some disadvantages. Below are the limitations of general science:

I.	Content	28
	Scattered information—no sequence	1
	Cannot be thorough in any one subject	11
	Too general for specific knowledge	5
	May lead pupils to think that future courses are as easy	1
	May be so hard as to kill interest in future courses	1
	May be bookish	1
	May go beyond the pupils' experience	1
	Will be repetition of topics for those who go on	1
	May take away interest for science later on	2
	May be made too difficult	1
	There is little of intrinsic worth in the course	1
	Hard to select topics on which to lay emphasis	1
	Supersedes physiology	1
II.	Lack of facilities	11
	Poor texts	1
	Lack of laboratory facilities	9
	Lack of properly prepared teachers	1
III.	Administrative	5
	Curriculum too crowded	1
	People too young	1
	Students neglect other work to read up on science	2
	Sections too large	1

The dissatisfaction expressed under the heading "Content" is well summarized by one teacher: Too many bites and not enough chewing. That depends on our aim. Are we trying to teach the pupil some of each phase of science or are we giving to the pupil an understanding, adequate to his needs, of such phases of science as affect his everyday life? Lack of facilities in many schools might as well refer to the other sciences also. But the disadvantages under the last two heads will disappear when general science is firmly established and the content of general science will be adjusted as specific aims are followed.

A state of affairs which is not only true for other subjects as well as for general science, particularly in small schools, is brought to light by the answer to the question, "What other subjects are taught by the general science instructor?" We find that of the sixty-five general science teachers who replied:

2 general science teachers teach no other subject.
15 teach one other subject.
24 teach two other subjects.
13 teach three other subjects.
11 teach four other subjects.

The following table shows what subjects besides general science sixty-five teachers handle:

No other subjects	2
Mathematics	1
Mathematics and athletics	1
Commercial	2
Other sciences	29

Other sciences plus one of the following:

Mathematics	9
Athletics	1
Commercial	2
Latin	2
Public speaking	1
English	2
Literature	2
Economics	1
History	1

Some of the bizarre combinations are due, no doubt, to the limitations of the school program; but many of them seem hard to justify on any grounds. Efficiency in the teaching of science, general or special, or any other subject will be increased as such combinations disappear.

Although general science courses are general in name, sometimes certain phases predominate. One school reversing the procedure reports that its general science course is scheduled as agriculture. The replies obtained from the question, "Does the course refer chiefly to physical, biological or physiographical topics?" are shown below:

Phase Predominating	In High School	Below High School
No particular phase	30 times	4 times
Physiography	9 times	.. times
Physics	8 times	1 time
Physical geography	..	1 time
Agriculture	1 time	..
Physiography and physics	8 times	..
Physiography and agriculture	1 time	..
Physiography and biology	4 times	..
Physics and physiology	1 time	..
Physics, physiology and chemistry	1 time	1 time

Another compilation of the above data shows:

Phase Predominating	Times Mentioned
Physics	24
Physiography	22
Biology	6
Chemistry	4
Agriculture	2
Physiology	2
Physical geography	1

One of the administrative problems that must be met when a new subject is introduced in the curriculum is, "Shall the course supersede another, or shall it be a distinct addition?" The following table shows how seventy schools answered the question, "What subject, or subjects, did general science supersede?"

Superseded Subject	In High School	Below High School
Nothing superseded	19 times	8 times
Physiography	28 times	2 times
Physical geography	5 times	..
Geography		1 time
Botany	2 times	
Biology	1 time	
Agriculture	1 time	
Physiography and botany	2 times	
Biology and physiology	1 time	

Considering the subjects separately, we find the following:

Subject Superseded	Times Mentioned
Physiography	33
Physical geography	5
Geography	1
Botany	5
Biology	1
Agriculture	1

We find that, in most cases, sciences that are superseded are not lost entirely in the curriculum as is shown in the following table in which only ninth grade subjects are considered:

Subject	Times Emphasized	Times Superseded
Physiography	22	33
Biology	4	1
Agriculture	2	1
Physiology	2	1
Physical geography	1	5
Geography		1
Botany		5

The wide difference of general science textbook writers on the contents of the general science course is shown in the following table, which is a revision of Table I "Number of Pages in General Science Texts Given to the Different Special Sciences" as given in "General Science in Iowa High Schools" by E. E. Lewis, *School Review*, June, 1916:

	Hessler	Clark	Snyder	Caldwell	Pease	Weckel and Thalman
Physics	150	249	67	76	74	51
Chemistry	88	56	10	12	22	59
Biology (zoology, botany, physiology)	178	26	82	131	48	230
Agriculture	10	0	15	15	2	7
Geology	14	0	198	19	83	20
Meteorology	26	0	41	39	12	29
Astronomy	0	0	30	3	31	0
Commercial geography	0	0	0	8	0	0

On account of the difficulty in distributing material appear-

ing in the texts, the above table does not accurately show the portions of the book spent on each specialized science. It is, however, sufficient for a rough comparison. We find that, considering all the texts together, they emphasized the phases of science in the order in which they are emphasized in the general science courses in the state, physiography first, physics second, etc.

Due to an unfortunate oversight while the questionnaire was prepared, no data are available to show what percentage of the whole number of pupils in the grade elect general science; we can, however, discover how interested the pupils are who do elect the course. In the answer to the question, "How do pupils show an interest outside the classroom?" we find the following manifestations of interest and the number of times mentioned:

Perform experiments at home and after school	23
Request information and explanation	5
Cite observations of phenomena	12
Interest in apparatus (wireless, engines, dynamos, manufacturing plants)	6
Bring specimens to school for identification (and apparatus)	9
Conversation outside of school	6
Bring clippings from papers	5
Outside reading (including systematic reading of scientific magazines)	7
Asking questions	13
Pride in note books	1
Applying principles to phenomena	10
Suggesting problems and explanations	3
Formation of science club	1
Use science subjects in English composition	1
Students now question what they once took for granted	1

One instructor declares, that, "there is not enough room on the paper to mention them all."

The above list also shows that the student is really interested in class as well as out of it. From their point of view, they are consciously getting an explanation of their environment. What better reasons for being interested are there than the fact that the principles studied explain things and intimate experiences—building fires, removing stains, keeping afloat in water, how a dynamo runs, etc. Anyone who has taught general science has experienced the joy of seeing pupils really enthusiastic and such enthusiasm, properly guided, can be made to realize any aim that can be formulated.

The following table is compiled from data received in answer to the question, "In what phase are the boys most interested? The girls?" The numbers given refer to the frequency with which the phases were mentioned:

Phase	Boys	Girls
Machines	1	....
Physics	9	2

Chemistry	7	3
Manual Training	1	....
Mechanics	1	....
Electricity	6	....
Practical	2	....
Practical experiments	4	....
Showy experiments	....	1
Astronomy	1	1
Botany	....	7
Zoology	....	2
Physical geography	....	2
Domestic science	....	10

These figures are not to be interpreted thus: The boys are interested in machines in only one school; rather in this fashion: in one school boys are predominantly interested in machines, being interested in other things also. Similarly for other figures. The table shows that the interests of the boys are along the lines that deal with the world in which they are living—the world of industry. The girls, as is somewhat to be expected, are interested in the practical affairs of the home; they also find interest in botany, zoology and physical geography—subjects which do not appeal to boys so much probably because the practical side of these sciences is not so apparent.

Answers to the question, "Is the course elective or compulsory?" show the following data:

In the high school, ¾ of the courses are elective and ¼ compulsory.
Below the high school, 1-3 of the courses are elective and ⅔ compulsory.
The majority of courses in the high school are elective; the majority below the high school are compulsory.

The following table shows what percentage of students who elect general science are boys and what percentage are girls:

Pct. of Boys	Pct. of Girls	Times Reported
50	50	9
55	45	4
80	20	5
70	30	4
60	40	11
90	10	2
40	60	7
45	55	4

We find that, on the average, the large percentage of students is boys. If we average the percentages and consider all the individual elective courses combined into a large class, we find:

Boys	61.4 per cent.
Girls	38.6 per cent.

The sizes of sections in general science do not vary very much from the size in other courses. Here are the data:

Number in Class	In High School	Below High School
Below 10	1	....
10-14 inclusive	2	....
15-19 inclusive	11	....
20-24	15	5

25-30 inclusive	18	12
31-34 inclusive	4	2
35-39 inclusive	2	0
40-50 inclusive		1

We notice that the sections are, roughly speaking, larger in the high school than below the high school, and that, considering the high school courses only, 33 out of the 53 schools reporting have classes between 20 and 30. The data available show that no general statement can be made about the relationship between the size of compulsory and elective courses.

The number of class meetings (including laboratory meetings) per week is shown in the following table:

No. Meetings	In High School	Below High School
5	51	11
4	2	---
3		2
2		1

Length of the recitation period is shown below:

Length	In High School	Below High School
45 minutes	52	6
40 minutes	4	1
60 minutes	2	1
20 minutes	1	1

The data received in answer to the question, "Is a laboratory used in connection with the course?" show that the following interpretations were made of the word "laboratory:"

I. Demonstrations made by the teacher in laboratory.
II. Individual laboratory work by students as is carried on in the specialized sciences.

At any rate, if we consider that the answer "yes" means that there is some other work besides the work in class, either as laboratory demonstrations or individual laboratory work, we find that:

90 per cent of high school courses have laboratory work.
40 per cent of courses below the high school have laboratory work.
10 per cent of the replies from the high school courses stated that they had class demonstrations; 37 per cent of courses below the high school have the same, so we may conclude that all the ninth grade courses have either laboratory or class demonstrations; 77 per cent of courses below the ninth grade have the same.

The manner in which the laboratory is conducted is shown below:

	In High School	Below High School
Laboratory demonstrations by teacher	40 per cent	75 per cent
Individual work by students	15 per cent	10 per cent
Both	35 per cent	15 per cent

The following table shows the nature of the laboratory outlines used in the seventy-six schools reporting:

Pease Laboratory Manual	7 times
Caldwell, Eikenberry, and Pieper	9 times
Hessler	7 times
Mimeographed directions	2 times
None	51 times

Of these, the directions are found in the back of Hessler's text; the other two are separate volumes. In the case of the fifty-one who have no printed instructions, the experiments are in some cases suggested by the text, by the laboratory manuals of the specialized sciences or by experiments from different general science manuals.

Home experiments are performed by students in 80 per cent of the high school courses, and in 66 2-3 per cent of the courses below the ninth grade. Note books are kept in 88 per cent of the courses having laboratory in high school and in 66⅔ per cent of the cases having laboratory below the high school. The following table shows the length of the laboratory period:

Time in Minutes	In High School	Below High School
40	3	----
45	31	6
60	3	1
90	1	11
80	1	----

The following table shows the number of laboratory periods per week:

Number of Lab. Periods	In High School	Below High School
1	15 courses	2 courses
2	20 courses	0 courses
3	2 courses	2 courses
0	4 courses	8 courses
Varies	12 courses	2 courses

Below are some examples of how some schools divide the time per week in high school general science:

High School Enrollment	Number of Recitations	Length of Recitations	Number of Laboratories	Length of Laboratory
133,335,70,270	4	45 minutes	1	90 minutes
45	3	40 minutes	2	80 minutes
550	3	45 minutes	2	80 minutes
400	4	45 minutes	1	70 minutes
250	4	30 minutes	1	60 minutes

The following table has been prepared to show the time spent per week on general science:

Minutes per Week	In High School	Below High School
90	----	3
135	----	2
200	5	----
225	40	5
270	6	----
300	3	2
315	3	----
330	1	----

It will be noticed that there are only a few instances of courses that do not meet at least five times a week; that in only one case is the length of the period under 40 minutes. As in the high school courses, 51 are 1 year courses and 8 are ½ year courses, it will be seen that in the great majority of cases at least one hundred 60 minute hours are spent per year in the course, thereby equalling the time spent in the recognized science courses.

General science is conceded by many to be in an experimental stage. Unlike some other subjects on the high school curriculum that are undergoing changes, it has not yet won recognition by the University of Michigan as a unit for entrance, although the faculty have been considering it for some time; as it now stands, the university is waiting for recommendation from the Schoolmasters' Club. With a view to ascertaining the opinion of the science men (the people who would be qualified to state one way or the other, as they are making the course) on the matter, the question, "Do you believe the general science course to be of such a character as to merit recognition as a unit by the university?" was added to the questionnaire.

One hundred thirteen replies were received to the question; of these 73 were from schools having the course, and 39 from schools not having it. The following table shows the results:

	Schools Having Course	Schools Not Having Course
Yes	67	23
No	5	15
Undecided	1	2

We notice that the ayes have it by a big majority in schools where the course is found; in schools where it is not found, more than fifty per cent are in favor of giving the course recognition. Combining the two columns we have:

In favor of recognition	90
Not in favor of recognition	20
Undecided	3

These numbers show that 88 per cent of those who answered the question are in favor of giving it recognition. A bigger percentage in favor of recognition is shown in the case of schools having the course. In those schools where we must consider that the advantages and disadvantages of general science are actually realized, the percentage in favor of recognition is 91 per cent. That only three reported that they were undecided shows that this question has been rather fully contemplated by those answering. There were many answers that read "emphatically yes," and in other ways showed that the instructors had no doubt about the matter.

The reasons given for thinking that the course should be recognized are as follows:

If the teacher is capable.
Ought to have as much recognition as other science.
Students will take it if the university gives credit.
If the course has a laboratory and is not a hodge-podge.
As course is largely physiography, and physiography was recognized, general science should be recognized.
It has a direct bearing on the observation of normal students.
It is as much an observation, thought and reason developer as any other subject.

The following reasons are given as not being in favor of recognition:

There is not enough unity of aim.
It is not standardized.

Of those undecided, all agree that action should be taken at once; in fact, there is a general opinion throughout the state that "something ought to be done about it soon." Some schools are in this position—although they consider the course as good as any other, and it is one that they want to recommend to students, yet they hesitate to do so when the student should be taking work for which he will be getting entrance credit at the university. This is particularly true in schools where the curriculum is crowded.

A complete list of universities and colleges that recognize general science as an entrance unit is not available. Practically all of the western universities allow a unit of entrance credit for it, as do several of the southern institutions. A partial list of universities recognizing it are: Chicago, California, Northwestern, Nebraska, Arkansas, Mississippi, Alabama, Georgia, Kentucky, Ohio, Iowa, Kansas, Texas, Brown, Washington, Oregon, Southern California, Oklahoma, N. Mexico and James Millikan. Several of the universities accept it from students who come from strong high schools; this is true of Illinois, where they have accepted it from good high schools for upwards of fifteen years.

General science is here to stay; and with university recognition, high school general science will take the place in Michigan schools that it merits.

HIGH-GRADE POTTERY NOW MADE IN THE SOUTH.

The effort to establish in the Southern States a pottery for the manufacture of high-grade ware has, after many years, at last been successful. In 1917, for the first time, white ware was manufactured in the South. The Southern Potteries (Inc.), began to operate at Erwin, Tenn., a ten-kiln plant for the manufacture of semi-vitreous porcelain table ware, using domestic clays exclusively.

RESEARCH IN BIOLOGY.

Conducted by Homer C. Sampson.
Ohio State University, Columbus.

It is the object of this department to present to teachers of physics the results of recent research. In so far as is possible, the articles and items will be nontechnical, and it is hoped that they will furnish material that will be of value in the classroom. Suggestions and contributions should be sent to Dr. Homer C. Sampson, Department of Zoology, Ohio State University, Columbus, Ohio.

XENIA.[1]

By Dr. A. E. Waller,
The Ohio State University, Columbus, Ohio.

If a garden with sweet corn happens to be growing near a field where the ordinary starchy corn of the "dent" or "flint" types are planted, and the pollen from the field blows into the garden, the mature ears of the sweet corn will show a sprinkling of starchy grains. Likewise, if a cross is made between corn with blue endosperm and white endosperm strain, if blue is used for the pollen parent, the seed will be blue, or mottled blue and white. These are examples of xenia. Xenia refers to the immediate influence of pollen in producing changes in the color or chemical composition of endosperm tissue. Whenever xenia occurs, the endosperm resembles that of the staminate parent and not the carpellate parent.

The striking feature of xenia is that the change is apparent in the seeds the same year that the cross pollination occurs, and before the embryo produced as the result of the cross pollination is grown. Fifty years ago this was regarded as phenomenal, or at least extremely puzzling to people of an age in which interest was often allowed to be captured by the merely curious things of nature. Coupled with this pseudo-scientific diversion was a widespread belief in telegony. By this is meant an alleged influence of a male parent upon offspring subsequent to his own. If a mare, for instance, which had borne progeny from matings with a zebra produced striped colts on subsequent matings with a horse, the stripes in these colts were thought to be a result of some far-reaching influence of the zebra mating. Notions of this sort are entertaining as myths, not unlike the willow wand method by which Jacob increased the number of his sheep at the expense of Laban's flock. However, such stories have no place in scientific literature. Yet at the time when xenia was first observed, belief in telegony was by no means limited exclusively to popular fancy. Xenia as a demonstrable fact had to be sifted out from such creatures of the imagination as just mentioned.

[1]Botanical Publications, No. 103.

That xenia should seem puzzling at first to plant growers and botanists is readily understandable. Did they not plant seeds that they could reasonably believe to be pure? Yet the seeds they harvested were often mottled or spotted in appearance. Further, from these spotted seeds, when planted, came a mixed population with all sorts of variations. As long, however, as such cases were regarded as being simply monstrosities or more popularly "freaks," there was little chance of discovering the processes in plants preceding the appearance of xenia.

First of all it was necessary to show that xenia is an actual fact and not a chance freakish occurrence. In some of the early observations of xenia not enough was known of the history of the seed used to make sure that cross pollination had not previously taken place. When, however, De Vries in 1899 published the result of some of his work, the fact of xenia was completely established. He used strains of corn in which it was known that there had been no previous cross pollinations—a sweet corn and a starchy corn. He found that sweet corn with starchy corn for the pollen parent always produced starchy grains. Here was an indisputable example of xenia producing a definite chemical change in endosperm composition. De Vries showed further that the kernels exhibiting xenia produced, when planted, true hybrids between starchy and sugary corn. We now know that such hybrids, if self pollinated, will in the second generation show the segregation of starchy and sugary endosperm in the usual Mendelian fashion.

About the same time that De Vries experiments were published, Correns concluded from some similar experimental work that the effects of foreign pollen cross pollinations were limited to the endosperm, and that the pericarp and other parts of seeds exhibiting xenia showed no changes. These two sets of experiments are referred to because they make clear the point that xenia is a definite occurrence, and second that it is limited in its effect to a particular portion of the seed, namely, the endosperm in which only the color or the chemical composition is altered.

The explanation of the mechanism by means of which xenia effects are produced came, however, from an altogether different source. August 24, 1898, is the date when Nawaschin announced before the Russian Society of Naturalists his observations on "double fertilization" in Lilium martagon and Frittilaria tenella. This is one of the greatest of botanical discoveries, and one which

has been so widely discussed that it only needs to be mentioned here. In brief, Nawaschin and the host of scientists who followed him established the fact that the endosperm of our higher plants is as much a product of fusion as is the embryo. The pollen tube discharge contains, at the time of fertilization, two male nuclei. The first fuses with the egg cell of the female gametophyte and forms the embryo. The second unites with a definitive nucleus or "endosperm nucleus" as it is called and forms the endosperm. This endosperm nucleus is usually itself a product of the fusion of two or in many cases several nuclei from the female gametophyte. A typical case is the one in which two polar nuclei from the opposite ends of the female gametophyte unite, and to this fusion is later added the second male nucleus of the pollen tube discharge. On account of the union, then, of three nuclei the term triple fusion is more appropriate than the somewhat ambiguous "double fertilization."

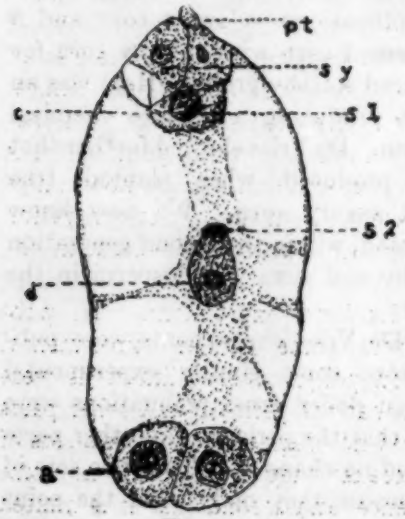

FIG. 1.

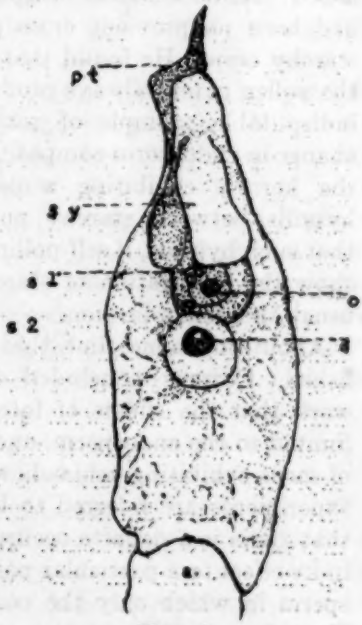

FIG. 2.

FIGURES 1 AND 2. DOUBLE FERTILIZATION.

FIGURE 1. Ranunculus cymbalaria (buttercup), entire embryo sac, showing two male nuclei, s1 and s2, fusing with the egg nucleus, o, and with the endosperm nucleus, d. The pollen tube, pt, and the two synergids, sy, are seen above and the antipodals, a, below; x360; after Guignard.

FIGURE 2. Helianthus annuus (sunflower), showing coiled male nuclei. The letters refer to the same structural parts indicated in FIGURE 1. After Nawaschin.

The figures reproduced here serve as a general illustration of the two types of fusion preliminary to seed formation. In the first figure, Ranunculus cymbalaria, the entire embryo sac is shown, the synergids at the top and the antipodals below. Just underneath the synergids the egg cell is seen fusing with the small dark nucleus of the first male cell of the pollen tube discharge, while in the center of the embryo sac is the second male nucleus in fusion with the endosperm nucleus. The second figure, Helianthus annuus, is quite similar, only the antipodals are not shown. In the buttercup the male nuclei are oval, while in the sunflower they are coiled.

After Nawaschin, Guignard in a great number of instances, Land, Strasburger, Miss Thomas and many other botanists have seen and described triple fusion. So great was the activity of these investigators that as early as 1903 the list of observations covered more than sixty species distributed among some forty genera and sixteen families. Since that time a number more have been added and are being added. The occurrence of triple fusion is now regarded as so general that it attracts interest only as further confirmatory evidence, and because there are irregularities and departures from the generalizations in the number of nuclei entering into the fusion. This need not be discussed here.

With the establishment as a fact of the fusion for endosperm formation as well as for embryo formation, the whole mystery of xenia was dispelled. Since the pollen tube discharge has two male nuclei, both originating from the same pollen grain, they may be considered potentially equal bearers of hereditary characters. In the female gametophyte, too, we find that the hereditary characters are of the same kind in the endosperm nucleus and the egg nucleus. Since the endosperm or definitive nucleus is formed from the fusion of nuclei that had divided from sister nuclei of the egg cell, the definitive nucleus must contain, qualitatively, the same hereditary characters as the egg. In point of quantity, however, there is a difference in the endosperm nucleus; for in the fusion of the two polar nuclei preliminary to endosperm formation, each polar nucleus brings a single set of chromosomes into the fusion or endosperm nucleus. But since each set has the same hereditary characters, and since a male nucleus like the one which united with egg fuses with the endosperm nucleus, it is to be expected that an endosperm will be formed partaking of all of the characters present in the fertilized egg.

That this is actually the case is shown by such experiments as those of De Vries referred to above, and which can be repeated by anyone.

If, for example, we cross starchy and sugary corn using starchy corn for the pollen parent, the mature ear at the end of the season, i. e., the generation in which the cross is made, will have starchy grains wherever the silk received the pollen bearing determiners for starchiness. Both the endosperm and the embryo are hybrids, but the condition of hybridity is evident only in the endosperm. If some pollen from the sweet corn was received by other silks on the same ear, we will have sugary grains scattered among the starchy grains. The wrinkled, sugary grains are, of course, pure. The embryo of the starchy grains like the endosperm are true hybrids between sugary and starchy corn. If these embryos are allowed to germinate and reproduce by self pollination, the first generation after the cross will have only starchy grains. But if the grains of this generation are allowed to germinate and produce a second generation by self pollination, the progeny show the usual Mendelian hybrid segregation of three starchy grains to one sugary grain. Xenia, then, can be regarded as an indicator of the hybridity of the embryo under certain conditions. We have only to know the history and nature of the seeds in order to understand what these conditions are. For this reason it will be interesting to consider for a moment the seed of corn. It has been selected as offering instructive evidence in illustrating the parts of a seed in their genetic relation to one another.

A botanist or a geneticist is not willing to answer the question "What is a seed?" by saying "What you plant." He thinks of the parts of the seed from the standpoints of their origin and from what later becomes of them if the seed really be planted. A seed is made up of three essential parts, the embryo, the reserve food materials and the seed coats. The embryo is a young plant and contains the sporophyte, or diploid number of chromosomes. This is usually designated as $2x$. The seed coats or pericarp are remnant tissues of the sporophyte plant which bore the ear. In corn, the pericarp consists of the ovulary wall, the inner and outer integuments of the ovule and the remains of the nucellus. These have coalesced into a single rather tough membrane in the mature seed. It might be mentioned in passing that since the ovulary wall is included in this membrane, a grain of corn is botanically a fruit, but this fact does not concern the present discussion. The seed coat contains

the sporophytic chromosome number since it is all tissue of the old sporophyte which bore the ear. If there were any remnant of the female gametophyte which had not been used up as food material by the developing endosperm and embryo, it would have the genetic constitution of x number of chromosomes, or the haploid number. The endosperm has a constitution of $3x$, or if several polars have joined in with the usual fusion in a multiple fusion, an "n" x chromosome number.

From what has been said we are now in a position to understand why xenia occurs. If a cross pollination is made between a race with dominant characters expressible in the endosperm and a race with contrasting characters, we have xenia resulting. The reciprocal cross in which the dominant characters came from the carpellate parent and the recessive characters from the staminate parent would not show xenia. As a process then, xenia is simply a part of normal seed formation. It is only when the male nucleus introduces dominant characters visible in the endosperm (or xeniophyte) that we have a change which once was regarded as surprising.

There are also certain cases on record which bear out beautifully the cytological evidence of triple fusion. In some crosses between corn with flinty and with floury endosperm, it was seen that no matter which way the cross was made, the grains resembled the carpellate parent. This is explained by Hayes and East on the ground that since the recessive, floury endosperm entered into the endosperm in two doses when it was used for the carpellate parent, and the dominant flinty as the staminate parent brought in only one dose, the single dose was not sufficient to show xenia. This is a splendid example of cytological evidence furnishing a theory for which experimental genetic work was necessary in order to establish proof. To illustrate the above, let the dominant character, flinty, be represented by H, and the recessive character, floury, by *h*. Then in a cross with the flinty for the staminate parent the endosperm would be H*hh* and no xenia would appear. The embryo would be H*h*, however. In this connection it is worth remembering that dominance of flinty over floury is a postulate only, since the endosperm with three sets of chromosomes always must express either one or the other character. The embryo has only two sets of chromosomes but the expression of the condition is revealed in the endosperm.

The photograph shows the result of some experimental work which can be carried out easily. The silks of an ear of white corn were carefully divided at the time of extrusion. On one

portion of the silks pollen from a race of blue flint was placed. The rest of the ear received pollen from the plant which bore it. An attempt was made to divide the silks so carefully that all blue grains would appear in about one-fourth of the ear and all white grains on the rest of the ear. The photograph shows how nearly successful this was. Only a few blue grains appear out of line and only one or two white ones in the blue area. Some grains that look almost white in the photograph were quite blue when seen on the ear. This simple experiment has a good deal of instructional value since it proves unquestionably that xenia as an outward demonstration of triple fusion can be secured as desired.

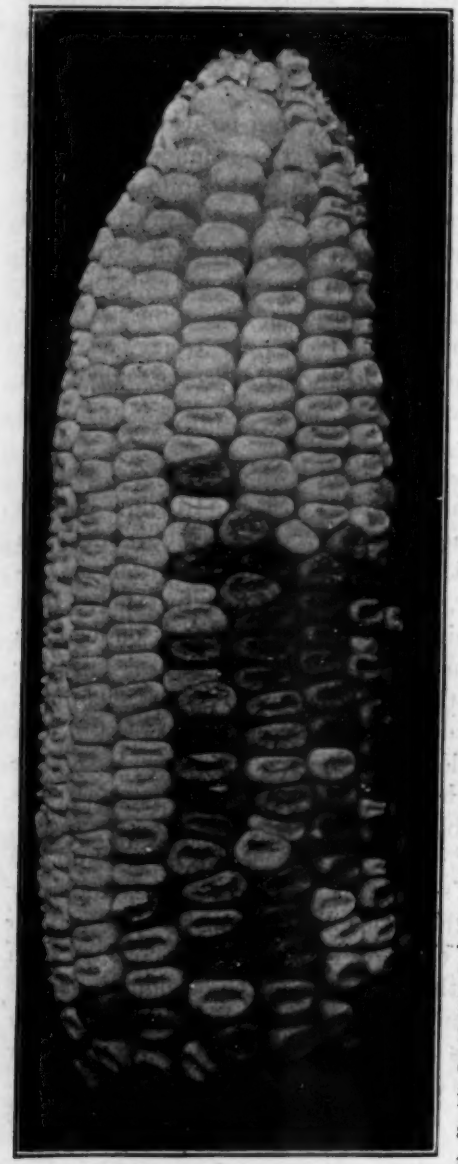

FIGURE 3. Photograph of an ear of white dent corn, a portion of which was pollinated by blue flint after carefully dividing the silks.

There are a number of variations of the experiment which could as easily be performed and which would serve as well. Instead of blue and white, starchy and sugary, or yellow and white, or flinty and sugary would serve as well for illustrating xenia. In the above pairs of characters the dominant is named first. It is only necessary to avoid pericarp colors, of which red is the most common example, in selecting material to demonstrate xenia. A character expressed in the pericarp

could not produce xenia, since the pericarp is old sporophyte tissue and is already completely formed before the endosperm fusion takes place. In the crosses between colored and colorless grains which show xenia, it is the color of the endosperm visible through a colorless pericarp.

This brings up another interesting point. Xenia occurs following endosperm fusion. Xenia cannot occur unless a fusion somewhat paralleling the fusion between egg and sperm has taken place. Physiological influences of a male nucleus on egg development or on the growth of tissues near the region of the egg cannot be called xenia. There are some not entirely confirmed cases on record of a change in the color of fowls' eggs and of canary eggs following hybridization. These have been styled "xenia." A geneticist, knowing the facts of xenia and xeniophyte, would quickly point out that such an influence, if genuine, cannot possibly correspond to our cases of double fertilization and xenia.

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THE UNIVERSITY OF CHICAGO.

Since 1892 more than 62,000 students have been in attendance at the University of Chicago for at least one quarter, according to the new *Annual Register* just issued by the University of Chicago Press. Degrees have been conferred, inclusive of these conferred at the Summer Convocation, June, 1918, upon 11,895 persons, including 1,106 who have received the degree of Doctor of Philosophy. Forty-seven honorary degrees have been conferred.

The members of the several Faculties now number: Professors 105, Associate Professors 46, Assistant Professors 53, Instructors 68, Associates 9, Assistants 95, Professorial Lecturers 11, besides library assistants, laboratory assistants, and readers. In all departments and in all grades of service the University employs about 1,300 persons.—[*University Press.*

NEW GEOGRAPHY AND OLD TEXTS.

By O. D. von Engeln,

Assistant Professor Physical Geography, Cornell University, Ithaca, N. Y.

This magazine, as well as other school periodicals, has in the past been and probably in the future will be guilty of publishing numerous short paragraphs of new developments in geography. The range of subjects these include is great. Up-to-date statistics are favorite matter. Opening of new routes, new canals, new railroads also get space quite frequently. Particular developments in a certain industry, the growing importance of a new product, all come within the varietal scope of these geographic pills.

Such items are intended to be of use to the geography teacher. But what is she or he to do with them? Probably the editor who finds them sets them down as copy and after they are in print promptly forgets them. That is an editor's privilege. Not so the poor teacher. Presumably he is supposed to memorize all this irritating miscellany, dragged together from the ends of the earth, in order that his teaching may be kept up-to-date. It is too much to expect. Even if the items were always carefully hand-picked, as it were, in order that only those most significant and worth while found a place, which often they are not, the strain of actually absorbing them all would involve time and energy altogether disproportionate to their actual educational and informational worth.

Yet there is a way to utilize such items in the classroom that will render the whole output available and may indeed, if it should be adopted generally, make an increase in the volume of such information desirable. By available is meant that the items are to be made significant to pupils, so that they will have pertinence in connection with their systematic studies; and a pedagogical value in that they will enlist natural human traits, interests, to the purpose of enlarging the geographic horizon.

It is a curious fact, in view of the modern dependence in teaching on elaborated texts, that, despite much painful memorizing and review of the subject matter which these texts present, so little of the actual meaning of the paragraphs and pictures is carried away by the students.

It is true that the class can, on the average, answer examination questions fairly well at the end of a term, but an oral quiz will in most instances very quickly reveal that there has been

but little real assimilation; the answers are merely the stringing together of various sets of words, which, even if they are not literal transcriptions from the text, at best only indicate a very circumscribed understanding of the topic involved. Little if any ability to correlate and interpret seems to be acquired. This may seem to be a rather sweeping criticism, but its general truth is indicated by the fact that it has been the writer's experience that students entering college do not even possess the ability to use an unfamiliar text as a source of information on a given topic. That is, if told to consult several books and get from each the facts on a given subject for presentation in a report on their reading, they usually show themselves hopelessly incompetent. They miss much that the authors have included, they fail to emphasize that which is important, they include more of that which is irrelevant than of matter that is germane. In a word, they don't understand what they are after and they don't know how to use the tools, texts, that they are supposed to have been accustomed to employ in twelve or more years of study.

Admitting that this is true, what can be done about it, and how are the items of geographic news to be of help in solving the problem? The answer is: By encouraging pupils to use their texts in a different way than that of conning so many paragraphs or pages each day and by using the current geography as a means to such an end.

It is a well understood fact that any science-text is out-of-date, even on the day it is published, because of the time that must elapse, and the changes that take place in that interval, between the day when the author ceases writing and the day when the book is finally printed and placed in the reader's hands. And a good text in a given subject is not produced every year. Even if such were the case, it would not be feasible to change the one in use in a given school so often. So that at best the geography text is apt to be considerably behind the times.

On the other hand, it is one of the most common human traits, if not indeed an exactly lovable one, to wish to criticize and correct what others have done. As opportunity offers, many students show this propensity in their endeavors to "catch the teacher." Why not give this spirit a wholesome outlet by setting it at the task of correcting the text? Concisely furnish students with the grist of new geography and make it their business to keep the text that is in use as up-to-date as the material will permit.

The practical application of such a scheme is capable of a variety of solutions. Perhaps as feasible as any would be that of securing two copies of the text in use, cutting them up into the separate pages and then pasting these pages in consecutive order in large scrap books, with a blank page opposite each page of the text. The old fashioned "Bill Books," formerly much used in business for pasting in invoices, will serve this purpose admirably and can be had at stationers generally, at low cost. Then, as new geographic items are published, let students look up the subjects to which they refer in the text, note the correction or additional information the items supply and incorporate this supplementary material in the reference, scrap-book texts by pasting in the new items on the blank page opposite the proper page of the text. At the point on the printed page where the new material should occur place a number in the margin, and the same number on the printed item that is pasted in.

Such correction and supplementing of the text need not be confined to the particular section of the text that is being studied at the moment. Everything should be utilized as fast as it is available. Such practice will familiarize the student with the use of the whole book, all of the time. It will make necessary the systematic use of the index. Correlation of the new item and the text statement will require thought in determining the differences indicated. If a given item is assigned to some one student or group of students for insertion or correction, followed by a report to the class, that student or group of students will need to understand what he or they are about in order to make an intelligible and pertinent statement of their work. Competition having regard for excellence in making such determinations could be introduced in this connection.

Whether the texts in the hands of the pupils should be marked up with the various corrections will of course be a practical problem depending on conditions of ownership, ability of students to make such annotations neatly and legibly, and similar considerations.

There can be no doubt that this is the kind of a task that pupils would "take to" with avidity. Students' preconception of the infallibility of the text would suffer a rude and useful shock and at the same time there would be developed an appreciation of the reasons why a book cannot be complete and final. As the items in the corrected, scrap-book edition of the text

accumulated there would be the opportunity to introduce each new lesson by a comparison of the unrevised and the revised version. The paragraphs to be studied would thereby acquire a liveness that would make their assimilation with true understanding much easier. Often, probably, there would arise questions as to the relative authenticity of the text statement and that of the new item; not all of the latter are thoroughly reliable; such particularly as may be gleaned from newspapers ought to be carefully scrutinized before acceptance. This would give opportunity for discussion. The teacher, of course, will need to exercise considerable editorial choice as to the items to be considered.

Other possibilities in connection with such use of current geography material will no doubt suggest themselves to ingenious teachers. The procedure indicated in the preceding paragraphs is only meant to be a clue. The idea is to put the new geography into the old texts; just how it is done is not so important, so long as the students get the opportunity to do it, and thus become acquainted with the subject in an understanding way.

It ought perhaps be added that textbook authors necessarily prepare in just this way for the issuance of new and corrected editions of their works. Hence, if a new text is offered to the teacher who has such a class-revised version of the text in use at hand, he or she can readily determine how up-to-date the new volume is and, hence, how worth while a change may be.

POSITIONS SOUGHT FOR ARMY OFFICERS NOW LEAVING CAMPS IN U. S.

The United States Employment Service today issued an appeal to employers in need of technical and other highly trained men to take on qualified men from the commissioned and enlisted ranks of the army who are now leaving the camps.

Hundreds of officers, many of the higher ranks, are asking the camp representatives and Federal directors of the Federal Employment Service for the States to assist them to obtain new employment. There also are large numbers of enlisted men qualified for professional and technical positions who are leaving the army without having positions in sight.

Among the men of this high type applying at the Federal Employment Service are engineers and other technical men, executives, chemists, statisticians, purchasing agents, employment managers, cost accountants, etc.

All employers wishing to get in touch with these men should communicate with the professional section, United States Employment Service, Department of Labor, Washington, D. C.

SCIENCE NOTEBOOKS.

By RAY MCCLELLEN,
Head of the Department of Chemistry, Davenport (Ia.) Senior High School.

The November issue of SCHOOL SCIENCE AND MATHEMATICS contained an article "Suggestions Concerning Science Notebooks in the High School," by Mr. John L. Dahl. I wish to make a few comments on this article.

His first statement, "The science notebook in the high school is a perpetual problem to the teacher," is a very true one. I think that all of us are agreed that the notebook could very profitably be left out of the science course entirely. There are only two reasons why I still use notebooks in my classes in chemistry, and they are both weak ones. One is because there are a few colleges in the country that require a pupil on entrance to produce his notebook in his courses in science. The other is that in my large classes I have not yet found a method whereby I know that each pupil has made some attempt, at least, to answer the questions involved. If I never had more than ten or twelve in my class, then the second question would not puzzle me.

The notebook is not an index of the orderly and systematic habits of the pupil and cannot be made to be. Some of the poorest pupils that I have ever had in all my years of teaching have had the very neatest of notebooks. Their apparatus and desk and notebook were about ideal but none of them knew very much chemistry and very little about systematic reasoning. But Mr. Dahl is very correct when he says that "If the teacher is slipshod in his methods as to apparatus, punctuality, notebook work, etc., his attitude will be reflected in each pupil." This latter cannot be emphasized too strongly. Neither can the science teacher be a teacher of spelling, penmanship and English —one of the best reasons for doing away with the notebook.

The loose leaf notebook is to be preferred but the questions should not be so arranged that they can be answered monosyllabically. This does not offer the pupil the opportunity of reasoning. When we have deprived him of that power then we have taken from him the purpose for which he is going to school. Man is the only animal which has the power of reason. Let us not take that away from him but help him to develop it.

Seeing a word continually spelled right is not sufficient to cause the average student to spell it correctly. It is only by the use of the word over and over and the writing of it over and over that it will be fixed permanently in his mind.

The idea that the notebooks are to be used "as reliable reference books later on" is one that amuses me. How many of us who have gone on and done more and more work in chemistry ever refer to any of our old notebooks? I have referred to some of my notes taken in the lecture room but never to any of my notebooks and never expect to. I trust that none of us will take this thought of his too seriously.

Sketches, or diagrams as I call them, are very essential in fixing a particular piece of apparatus in a pupil's mind. But is this of any real value? Has the experiment been performed to impress upon the pupil's mind a particular kind of apparatus? There are very few experiments which require a definite kind of apparatus. Most of them may be performed with a variety of pieces of apparatus. How often does the teacher have to use a different piece of apparatus from the one mentioned in the instrucions. I never allow the pupil to make pictures of the apparatus. It must always be a diagram. Yes, sometimes I have had my pupils copy a diagram in order to try and impress it upon their mind. This is very seldom necessary, though.

If notebooks are to be used, they should be handed in by the pupil after the completion of every exercise and then looked over by the instructor and returned to the pupil. The habit of letting the exercises remain in the hands of the teacher until the end of the month or term is a bad one. Complete the exercise while it is still fresh in the mind of the pupil.

But the sooner we get away from the notebook habit and get our pupils to do the work because of their interest in it, the better it will be for both pupil and teacher.

WAR ACTIVITIES OF GEOLOGICAL SURVEY.

The special training of the Geological Survey engineers made them available for effective war service both overseas and in this country. The large amount of technical data collected through the years by the Geological Survey was found to possess a value not anticipated; and the official machinery organized for scientific investigation of the subjects within the Geological Survey's province was also utilized in the more intensive inquiries required as each industrial or military need arose. The increase in the Geological Survey's representation in the Army from 61 men at the beginning of the fiscal year 1918 to 322 at the end of the year (462 on November 11, 1918) necessarily involved a serious reduction in the man power available for other contributions to war work. Yet it is believed that both in variety of scope and in volume of results the war activities under direction of the Geological Survey, Department of the Interior, were more important during the closing months of the year than ever before.—[From Annual Report of Director United States Geological Survey.

HIGH EXPLOSIVES.

By CLARENCE TALBOT.

Explosives date back as far as 660 A. D., when the Greeks used a mixture of pitch, resin, saltpeter and sulfur in a compound called Greek fire. The modern smokeless powder should be credited to the inventive genius of Vieille, who was the first, in 1886, to produce smokeless powder.

Explosives are either mechanical mixtures or chemical compounds. First, let us take up the former group, that of the mechanical mixture. Gunpowder is typical of this group. Gunpowder consists of sulfur, saltpeter and charcoal mixed together. When enough heat is applied the three substances unite to form a large amount of gas at a high temperature. The typical example of the second group is nitrogen iodide. When dry nitrogen is touched it breaks up into its elements with great explosive violence. With nitrogen iodide there is no combustion, in fact the compound *will not burn.* (Illustrate.)

Theory of Explosives.—An explosion may be defined as a chemical reaction which is effected in an exceedingly short space of time with the combustion of a large amount of gas at a high temperature and accompanied by a shock. When the explosion is progressive, that is, starts at an initial point and continues from one point to another, the action is termed burning. When, however, the action is effected simultaneously throughout the mass, the action is called detonation.

Most explosives consist essentially of compounds containing carbon, oxygen, and nitrogen, the latter of which is in a state of feeble combination with the whole or part of the oxygen, this constituting an unstable chemical condition which is necessary. When the explosion takes place, the nitrogen gives up its oxygen to the carbon, for which it has a greater chemical affinity. In most explosives the carbon is accompanied by hydrogen, which by its combustion produces water in the state of greatly expanded vapor. Other subordinate elements are often present: thus, for instance, in gunpowder the potassium holds the nitrogen and oxygen loosely together as saltpeter. And there is sulfur, a second combustible, whose oxidation evolves even greater heat than carbon. The foregoing description illustrates those explosives in which the action may be considered a process of oxidation, but there are cases in which an explosion occurs by the simple dissociation of a compound without oxidation; thus nitrogen chloride and nitrogen iodide contain neither oxygen

nor carbon, and their great explosive violence is explained by the feeble affinity of nitrogen for other elements.

Explosive Compounds Derived by Nitro Substitution.—This class consists of a series of compounds formed by treating certain hydrocarbons of the aromatic series, which are for the most part coal-tar derivatives, with nitric acid, producing a new chemical compound which is relatively unstable, and contains elements that are capable of uniting at a high temprature to form stable gases. Nitrobenzene is a good example of this class of explosives.

Explosive Compounds of Nitro Derivatives.—This group consists of the nitric esters, either of cellulose or glycerine. In the first case the cellulose is treated with nitric acid forming guncotton, and in the second case glycerine yields nitroglycerine by the action of nitric and sulphuric acids.

Guncotton is the very important member of the group. It consists of a cellulose, such as pure cotton treated with a mixture of strong nitric and sulphuric acids for about six hours or longer. The cotton is then taken out and washed to get rid of all acids; a solution of sodium carbonate is then added to remove all traces of the acids. The guncotton is then left slightly alkalin to neutralize any acid which may be formed later. For explosive purposes the cotton is pressed into a solid block and detonated by a cap, dry cotton next to the cap and wet cotton outside of that, as wet cotton is hardest to detonate but is more violent in the action when once started.

Smokeless powder represents the latest development of explosives containing guncotton. It consists chiefly of either a guncotton which by the aid of a solvent has been converted into a colloid mass, which when dried is a hard hornlike material which may then be formed into flakes or cords; or of a powder in which a mixture of guncotton and nitroglycerine is transformed into a similar hornlike substance either with or without the aid of a solvent.

Nitroglycerine.—This most powerful explosive, which explodes violently at 180 C., was discovered by Ascanio Sabrero in Turin, Italy, in 1847, and is a colorless or light yellow oily liquid made by pouring pure glycerine into a mixture of concentrated nitric and sulphuric acids. A mixture of concentrated nitric and sulphuric acids is taken in the ratio of one and two; the glycerine is then sprayed into the mixture. One must be very careful to keep the temperature below 180 C. or an explosion will result.

After some time the nitroglycerine will come to the surface in little globules. The glycerine is then drawn off and washed to remove the acid. Sodium carbonate is then added as to guncotton. The nitroglycerine is then dried, after which it is ready for use. The tendency of nitroglycerine to decompose, resulting in a violent explosion, has led to the abandonment of it as an explosive, but when combined with a suitable absorbent, the propety is removed, and has given rise to a very important series of explosives known as dynamites, which may be again subdivided into two principal groups, namely, dynamites with an active absorbent and those with an inactive absorbent. The first group comprises those dynamites which have an active absorbent, usually a nitrate mixture. The second group comprises those dynamites which have an inert absorbent as represented by those original dynamites in which kieselguhr is used as the absorbent. This dynamite is made in strength ranging from nitroglycerine 75 parts and absorbent 25 parts to nitroglycerine 30 parts and absorbent 70 parts.

Sprengel Explosives.—In 1873 Dr. Herman Sprengel described a class of explosives consisting of two inexplosive ingredients, which when mixed together yield a compound capable of violent detonation. Rack-a-rock is the best example of this group, although the picric acid compounds are sometimes included under this head.

Fulminates and Amides.—The fact that certain nitrates, when heated with alcohol and an excess of nitric acid, yield peculiar crystalline, easily detonating precipitates has been known for more than a century., The best known member of this group is mercury fulminate, which is made by dissolving mercury in an excess of nitric acid to which solution alcohol is added. The gray explosive mercury fulminate is thrown down by the addition of water. The precipitate is then carefully washed and dried. It is exceedingly sensitive to heat and shock of any kind, and may be detonated by heat at a temperature variously given from 140°C. to 200°C. The mercury fulminate as well as silver fulminate finds extensive use as a detonator for guncotton and nitroglycerine compounds.

The Amides, such as nitrogen chloride and nitrogen iodide, have been referred to under the Theory of Explosives, and have no economic interest.

Germany has a monoply on the manufacture of explosives, because she has a corner on the world's supply of nitrates, and

on the distillation of coal tar from which some of the highest explosives are made. America can manufacture the explosives and distill the coal tar in the laboratory, but she has yet to learn to manufacture them on a commercial scale profitable so as to compete with Germany. At present the United States manufacturers are producing vast amounts of explosives, but after the war if they are not given government support they will go out of business. If the government will foster the dye industry with the understanding that they are to turn their dye plants over into explosive plants at the start of war, the United States will be able to compete with Germany along the dye and explosive line.

WHAT BELONGS IN A HIGH SCHOOL CHEMISTRY COURSE?

It seems to be the style nowadays to criticize various phases of present-day high school chemistry work. If such criticism encourages or directs the efforts of somebody who has a good textbook unwritten, the discussion may be of profit.

The writer handles classes of boys only. He has no opportunity to sit back and listen in comfort to copious recitations delivered "en bloc" by the faithful girls. Perhaps he assigns a few pages, paragraphs or topics out of a standard text; but he has learned not to expect the boys to master all the details in the lesson. Boys are not on the whole industrious enough for that—at least not in our balmy climate. Our complaint is, "too much material in the text."

It is not sufficient to say that the teacher should omit what he doesn't need. This is impractical in most cases, since the unnecessary material is dovetailed into the essentials so closely that it is often out of the question to segregate it. High school pupils are not mature enough, haven't enough discretion to pick out the essentials in a chapter that is padded with unnecessary discussions. Result—superficial habits of study and not much definitely understood.

We need only ask an instructor in first year college chemistry to find how little we can depend on the high school student knowing chemical theory. The college man expects such a student, coming to him with credit in secondary chemistry, to be familiar with the general language and expressions of the science, and to be able to learn the subject over again a little bit faster than the absolute novice could. The professor then fondly hopes that the subject can be developed properly in the student's mind without extra time devoted to uprooting false ideas. One

college professor told me that he would far rather have a freshman come to him with some ideas in density, the metric system and a few other topics in physics, than to come with a course in high school chemistry!

The natural issue of our objection is to give concrete examples of material which does not belong in the high school course, or at least not in the first semester.

Determination of atomic and molecular weights is a topic belonging largely in college. Dulong and Petit's Law is a waste of time in the high school course. Freezing-point and boiling-point determinations of molecular weight are fine bits of knowledge, but also a waste of time to the high school pupil. To be sure, pupils may learn the governing laws, but can better spend their time studying practical chemistry of more value.

The ionic theory has spread itself into a large place in the freshman college course; and the inevitable result is the dragging of unnecessary theory down into the high school. To the mediocre and dull student the problems of abormal freezing point, hydrolysis and other ionic equilibria are of little importance. The small portion of the ionic theory which does belong in the high school course should be taught early, consisting mainly in the use of it to present the idea of two-fold characteristics of acids, bases and salts. In other words, the teacher should give an experiment showing the electrolysis of a number of dissociated substances, for one prime purpose: to pound into the student's head the idea that reactions between the electrolytes take place primarily between the entire undivided radicals, and not by a general jumble and Chinese puzzle of atoms. To this demonstration the explanation of electroplating lends the needed element of interest.

To place Boyle's Law, Charles' Law and the vapor tension table before the third-year high school pupil at the front of the book is most undesirable. What conception has such a pupil of the term "gas" after a brief discussion of the first gas he ever produced, viz., oxygen? The only real justification for placing the difficult topic of gas corrections so early in the course is to provide a means of getting the equivalent of magnesium or sodium. The determination of an equivalent can be performed better by letting the pupil synthesize cuprous sulphide in a porcelain crucible, where he can see everything involved in the experiment and actually weigh the reacting substances. If the teacher desires at this time to obtain an equivalent by measur-

ing gases, let him announce to his class a specially corrected tabular figure for the weight of a liter of hydrogen at the conditions of the experiment. In this plan a pupil is not lost in a mass of 273's and 760's in his attempt to get at the point of the experiment. After all, why is it any more illogical to announce that "a liter of moist hydrogen measured at the conditions of our laboratory has been found to be .083 gram" than to announce that one liter of dry hydrogen at O° and 760 mm. weighs .09 gram? Probably the laboratory never presented the standard conditions called for in the tabular figure. Of course, after the class has proceeded several months, Boyle's and Charles' Laws can be taught and applied readily—that is, after the pupils have seen several gases and have some idea of the meaning of the term gas. The experiment on the equivalent of magnesium is usually very inaccurate, since the hydrogen produced is not at all pure, but instead contaminated with nitrogen and other gases in equilibrium with the gas-saturated water of the containing tube or vessel. This factor often causes more error than would have occurred had the pupil forgotten the entire temperature correction.

Valence as a logical product of reasoning comes later in the study of inductive chemistry. That is, only after a multitude of reactions are studied does any mathematical law of combination appear. In the high school course, however, valence is explained not as general information, but as a practical tool. Theory of valence is not of interest to the beginner; but the rules for using valence should be brought out as soon as the text makes clear the concept of atoms grouping together into molecules. This stage ordinarily comes after a few chemical compounds have been studied. Why make a student plow around in the tangle of equations week after week without valence rules to straighten out his formulas? Without this convenience the writer finds it necessary to send his students to much useless investigation of formulas in reference books when they might as well be getting practice in using valence laws.

You can teach the bright pupil out of any text, in most any order. But how many mediocre or dull pupils can follow the laws of definite and multiple proportions up through Dalton's reasoning into the atomic hypothesis? Much of this is wasted on the ordinary beginner's mind. Better present the simple fact that a compound is homogeneous—that the smallest particle mechanically obtainable contains all the ingredients; there-

fore, the ingredients must exist in very small pieces tied together or combined in some peculiar way. Such reasoning doesn't bother anybody, is sufficient for a practical working basis and is enough for high school pupils.

Many other topics could well be omitted: e. g., formation of hypochlorous acid in bleaching reactions; heat of neutralization, taken up quantitatively; nitrides; phosphonium; details of the various phosphoric acids; complicated organic chemistry without time to really impress anything on the student. The metathesis of ammonium nitrite, performed during the elementary study of air, is largely jargon to the pupil.

Within recent years there has been much demand for "practical chemistry" in the high school course. This demand has led to at least two developments: First is the introduction of a lot of pseudo-chemistry, particularly of the "household" variety. Witness the high school pupil "analyzing" his saliva, tea for caffeine; diazotizing aromatic intermediates into dyes, etc. Such amusements are fine material to fill up warm days near the last day of school.

Another development of practical chemistry is the study of factory technology. It seems that this too has questionable value. Elaborate diagrams of smelters and furnaces of various types do not always benefit a pupil to a marked degree. Technology changes so fast that factory processes are sometimes obsolete before a text serves a year's duty. Why not devote some of the time to a better understanding of chemistry involved in the use of common substances? For example, why not discuss more adequately the chemistry in such topics as these:

Troubles in the use of soap in hard water.
Problems in keeping iron from rusting.
Properties and behavior of hydrocarbons used in automobiles.
Bluing in clothes: advantages and troubles.
What happens when powder explodes.
Home gas stove—adjustment of *gas* inlet as well as *air* inlet, style of burner, etc.
Troublesome chemicals in the soil—remedies.
Simple chemicals used in medicine, sanitation and farm work. Poisons and antidotes.

In this list there is no intention of presenting a lot of superficial chemistry where the teacher cannot get the subject down to equations.

If local manufacturing plants are available, let them be visited and studied; but the beginner should not be bothered with much far-distant technology when the processes cannot appear before

the student's eye. To demand a study of a chamber process acid plant is going too far, unless there is a plant of this type in town where the pupils can get the actual industrial viewpoint. Lantern slide, charts and models are inadequate substitutes in this field.

What does need emphasis in the high school course, and repeated emphasis, is the formation of acids, bases and salts in both the wet and dry ways, with ample equation practice. This involves another rearrangement of orthodox schemes. For example, when the topic "nitric acid" is broached, a number of nitrates should be studied at that time. No harm is done by bringing in the study of the metals as an early point. In fact, the metals are the one class of elements that the beginner knows best. The place to study baking powder, baking soda, washing soda, plaster, hard water, limestone, is in the section on *carbon*. Why leave the treatment of these very useful everyday compounds to a job-lot chapter studied at the end of the course? The potassium, sodium, magnesium and calcium ions, considered from their own standpoint, are colorless uninteresting substances, though their compounds are most vital studied in the proper connection. The reader need not be told that the latter chapters in some texts often degenerate into monotonous catalogues of salts of metals. The reader may also know what trouble arises in making a live manual of experiments to accompany such chapters, coming after the study of the non-metals is passed. Some laboratory manuals take up metal after metal, calling for test after test of properties, beginning nowhere and ending nowhere. Little impression is made. To avoid the dullness of this type of course, many high school teachers resort to qualitative analysis and rouse interest if nothing else. This plan is widely condemned, and likely with justice so condemned. It is probable, however, that the spreading out of the interesting non-metallic elements in the laboratory study would decrease the problem.

Finally, to get at the real problem of high school chemistry: Is there not some way to give the dull but conscientious student a chemical skeleton of essentials that he can lay hands on and master, presenting at the same time adequate material to keep the brilliant fellow working up to his mental standard? This may mean the segregation of much of our present text into some sort of an appendix with proper references. More than that, there should be sufficient latitude in choice of experiments that

a teacher may compile his own manual. In this way an enterprising publisher might stock a list of two hundred or more loose-leaf experiments, all provided with questions properly referring to a text in which the desired information is simply and accurately presented. These would include numerous teachers' experiments to be selected according to the extent of equipment in the school. Additions would be made to the list, or revisions, by the publisher from year to year at little expense. While there would likely be in this list a small "irreducible minimum" of standard experiments necessary to any course, there would still be much latitude; and in this manner both city teachers with elaborate equipment and country teachers could be suited.

EARL EASTMAN.

President Earl Eastman of the New Jersey Science Teachers' Association died at his home in Atlantic City during the Christmas holidays from pneumonia, following an attack of influenza. This news comes as a great shock to his many friends among the teachers of the state, where his progressive methods and sincere devotion to the advancement of science teaching have made him widely known.

TEACHERS' SALARIES IN PEACE TIMES.

How will a return to peace affect teachers' salaries? Will they be as low as during the pre-war period, or will war salaries be maintained? The general belief seems to be that with the release of many teachers from the army and government work, there will be a great supply of teachers and that salaries will get back to the old schedules. The Albert Teachers' Agency, 25 E. Jackson Boulevard, Chicago, has issued a new edition of its booklet, *Teaching as a Business*, in which it takes issue with the low wage theory, and contends that war salaries will not only be maintained, but that they will be higher than ever. The booklet, of general interest to school officials and teachers, will be sent free to anyone desiring it.

THE CARBON-PROCESS.

It seems a pity that at a time like the present, when circumstances are so much against the more ordinary photographic processes, so little is heard of carbon. In it, we not only have a method which has an infinite range of colors and surfaces, as well as a high reputation for permanence, but one the materials for which are less affected by war-conditions than those for any other. The extreme purity so necessary in paper for silver printing is not required in the carbon process; while gelatine of suitable character, and a long list of pigments, are still obtainable quite easily. Even if the shortage of potassium compounds makes the price of potassium bichromate a high one, comparatively little of it is required; and that little can be replaced by ammonium or sodium bichromate without any ill result. Indeed, some workers have always used ammonium bichromate as the sensitizer. Carbon-printing really ought to respond to a little judicious pushing at the present moment.—*Photo-Era.*

HOW CAN SEX INSTRUCTION, WHICH HIGH SCHOOL BOYS AND GIRLS NEED, BE GIVEN IN CONNECTION WITH BIOLOGY?[1]

By H. R. HUBBARD,

High School, Plainfield, N. J.

I do not flatter myself that I have anything new to offer. In my teaching of biology I have, however, developed a method of approach to and of presentation of the subject which may be different from the methods used by some of you, and thus not devoid of interest. The amount of sex instruction that can be given to high school boys and girls varies according to the community and the character of the class. Some communities are much more progressive than others. The teacher can give much more information in classes of one sex only than in mixed classes. In each case he must size up the situation and determine how far into the subject it is wise to go, and whatever he does teach, he should teach fearlessly and clearly.

As the time at my disposal is too short for an extended discussion of the subject, let us assume that the teacher is located in a progressive community and is teaching mixed classes.

What sex instruction do the high school boys and girls need? It seems to me that they should have a general knowledge of the structure and function of the reproductive organs and cells, of fertilization and the development of the embryo, of the hygiene of the reproductive organs, of the relation of immorality to venereal disease, and lastly, of the inheritance of traits or tendencies of social importance.

These topics, widely different as they are, are all based upon the phenomenon of sex, and a knowledge of all of them will be most useful to the young woman and young man, either as regards his individual health or his conduct in relation to others.

It is possible to treat the entire subject of reproduction and sex instruction at once, spending perhaps a week on it, and ignoring it during the rest of the course. I feel very strongly, however, that it is better to continue the study of reproduction throughout the year, dropping it and picking it up again, approaching it from different points of view in exactly the same manner as any other life activity. The class soon accepts this attitude and shows no more embarrassment in discussing the phenomena of reproduction than in explaining the processes of digestion or excretion.

[1]Read before the New Jersey Conference of Educators, Newark, N. J., December 14, 1918.

The musician Schumann once said in speaking of composing a symphony, "The beginning is the main thing. Once you are well started the rest is easy enough." This observation applies no less to the subject of sex instruction than to that of symphonic writing. If the sensibilities of the pupils are rudely shocked by the first presentation of the subject of reproduction, a feeling of aversion may quickly develop—a most unfortunate condition.

The best method of approach is, undoubtedly, through some common oviparous animal or some familiar plant. For years, I have begun with the frog. The pupil discovers in his dissection, along with the other organs the ovaries, spermaries and ova. A microscope slide reveals the sperm cells.

The development of the frog naturally follows. If the attraction of the sperm to the egg, fertilization and the consequent changes in the chromosomes are explained as a series of chemical reactions, each of which initiates the next, the pupil gets a very different conception of these processes from that given in the various so-called purity books. These books have their place, but the mystery and sentiment with which they enfold the subject would be fatal to a healthy classroom discussion. A short account of the experiments of Loeb on germ cells and artificial fertilization as explained in his "Mechanistic Conception of Life"—University of Chicago Press—will at once create in the class a mental attitude which is incompatible with morbidness or sentimentality. To illustrate the phenomena leading to the first cleavage of the egg a chart is necessary. The teacher can readily prepare one from any series of illustrations. An unusually good series is to be found in Prentiss and Arey's *Textbook of Embryology*, W. B. Saunders and Co. If the chromatin and chromosomes are colored in two different tints, the chart can be used later in showing the inheritance of traits as explained by Mendel's Law. The pupil should be taught the development of the blastula and gastrula and the formation of the principal organs and tissues from the three germ layers, helped by charts and models. At this point it is well to emphasize that all animals and plants develop in a regular way and that the development of the higher animals, including man, is in fundamental respects much alike.

Following the frog, my classes study the bean and compare the principles of reproduction of the two organisms. There is no reason why the plant should not precede the animal if the teacher prefers. Then come in turn, fern, moss, spirogyra—interesting as a simple form of sexual reproduction—molds, yeast

and bacteria, illustrating asexual reproduction. When studying bacteria it is possible to show under the microscope or by chart the gonococcus and spirochaete along with T. B. and other types, and at this time take up the matter of venereal disease. The teacher can explain without going into undesirable detail that infection can take place indirectly through the use of public toilets, towels or cups, or directly through the reproductive organs by immoral acts. The pupils should also be warned of the prevalence of venereal disease—far greater than is generally supposed by the layman—and informed of proposed methods of safeguarding the public. The children of today are to be the voters and legislators of tomorrow. If we neglect to interest them in vital social and economic problems while we have them in our hands, we are missing our greatest opportunity to mold public opinion and advance legislation which shall have a sound scientific basis.

After studying reproduction in the plants, reproduction in the animals lower than the mammals offers no difficulty. Just before taking up the subject of mammalian reproduction, my pupils review the different types of reproduction already studied, comparing division, budding, conjugation and fertilization in animals and plants, and working out roughly the evolution of sex. A good reference book is *Sex*, Home University Library, Henry Holt and Co. We then study the monotreme, the marsupial, and higher orders, emphasizing the development of the uteri from the oviducts and their fusion into a single uterus. Then we discuss the function of the placenta in its relation to the problems of nutrition, respiration and excretion of the foetus, and the possibility of the inheritance of disease. The lesson on "mammalian reproduction" is, I will admit, one that requires considerable tact. It is most successful when we treat it as an informal lecture, followed by a review quiz the next day. I find then that the pupils are quite ready to talk and show little if any embarrassment.

I do not see how the hygiene of the sex organs can be taught in mixed classes. The only way is to separate the boys and girls and have them instructed by a teacher or physician of their own sex. If this is done, more instruction in venereal disease and social evil can be given.

The climax of every high school course in biology should be a study of Mendel's Law with its applications to plant and animal breeding and human inheritance and eugenics. The pupil should

be taught the seriousness of marriage and of social evil from the biological standpoint, by a study of the inheritance of feeble-mindedness, mental disorders, tendency to tuberculosis, albinism, etc., as well as of traits beneficial to the human race. Each pupil can work out his own eye-color inheritance as an introductory exercise, showing how it follows Mendel's Law. The Jukes and Edwards families furnish good material for illustration. The story of the Kallikak family, published by MacMillan and Co., is an admirable object lesson and should be read by or at least known by every boy and girl. The teacher can obtain much valuable illustrative material from the Eugenics Laboratory, Cold Spring Harbor, N. Y.; from Goddard's *Feeble-mindedness—Its Causes and Consequences*, MacMillan and Co.; from Castle's *Heredity and Eugenics*, University of Chicago Press; Davenport's *Heredity in Relation to Eugenics*, Henry Holt and Co.; and Punnett's *Mendelism*, MacMillan and Co.

So far I have said little of the attitude of the teacher. His treatment of the difficult question of sex instruction in all its aspects should be the same as his treatment of all other biological topics—cool, scientific, forceful. The pupils, especially at first, will be on the lookout for any difference in presentation and tendency to evade the issue. Embarrassing questions will sometimes be asked by unsophisticated or over-sophisticated pupils; they must be answered squarely but tactfully, unless an answer before the class is impossible. If the teacher has not the poise, alertness and courage to meet these situations, he will do well to avoid the subject of sex instruction entirely. One slip on his part will impair the confidence of the class in him as a teacher and make further instruction in this line extremely difficult. But what about the inexperienced teacher? How can he know whether he possesses the necessary qualifications to cope successfully with this problem? Only by testing himself. It is well worth while to make the attempt once, at least. The best preparation is a study of the work of the modern experimental biologists, Bateson, Morgan, Davenport, Castle, Loeb, so that he may emphasize the chemical, physical, and Mendelian aspects of the phenomena and have plenty of illustrative material at his disposal. If he proves equal to the task, there is perhaps no part of his teaching which will bear better fruit in the lives of his pupils and have a greater social value to the community in which he is laboring.

"DEMOCRACY AND EDUCATION."

By WILLIAM B. BORGERS,
McKinley High School, Chicago.

In Dewey's great book with the above title, we get a vision of an ideally perfect world in which all learning is by doing useful things; and conversely, all necessary work is so directed as to have educational value. Moreover, since the worker is at every step conscious of learning something that he wants to know, and at the same time sees the value of the things produced by his work, the doing affords him constant pleasure. Thus there shall not be one time and place for work, another for study, and another for play, but every act will fulfill all three functions at once; and no man shall say to another: "Do this"; for everybody will be doing his duty because he likes it.

But in our present world, every person must do, every day, things that he would rather not do. In school, he can always blame the teacher for not making it sufficiently attractive, for not making its purpose clear to him, for not discovering each pupil's "need," and leading the pupil to see it and to choose the right activity for its fulfillment; or for not providing the means for carrying on this activity. But at home, in the shop, or on the farm, he must keep on doing a necessary task long after its educational possibilities, as well as the fun of it, have disappeared.

The ideal way to learn bookkeeping would be to start actually keeping books, or at least figuring up accounts. If this were possible, then the saying, "Education is not preparation for life—it is life," would be true. But in our present world, no employer will put in his accounting department a person who has not at least the rudiments of the Three R's. Figuring up an account involves so many things at once that the beginner must take them up more or less separately—learning to read, to write, to figure, to reason out problems, and then to put an account in proper form—before he can begin to do anything that has commercial value. The telephone operator must take a course of preparation in which she answers many calls, merely to learn to do it, before she can be trusted to do anything besides learn. While it would be an exaggeration to say that this course would have no meaning or value except as a preparation for telephone operation, it certainly would not have enough that anybody could afford to take it otherwise. That is, such a bit of education is only preparation, not life. Yet a telephone operator's

work involves so few elements that the learner can master them in a few days, and during the whole time she can see the need of learning each thing. The task of the bookkeeper or the stenographer is far more complex, and hence his preparation must be far longer. And the necessity of separating the numerous elements and simplifying them for the beginner makes it impossible that he should always definitely see the aim of each step before he takes it, much less choose his path, however desirable that ideal is. This is true now to a far greater extent than it was before the telephone, the electric light, motors, and gas engines became part of our daily life; before calories and proteids formed our diet. And as our life becomes more complex, as we use more elaborate machinery, and more science and mathematics become necessary for the directing of our affairs, this will become still more true. In a savage community, education consists almost entirely of learning to do things; and things, for the most part, that everybody in the tribe learns to do, and that are immediately and obviously useful. Moreover, though they may require considerable dexterity, they do not require such an amount of preliminary knowledge as do most of our civilized occupations. Hence, as Dewey remarks, such a community would be astonished to hear of a place where people go just to learn.

We could get part way back to the savage's unity of learning and doing if every employer had a clear vision of Dewey's glorious ideal, and if he had also the necessary knowledge and the skill in teaching, as well as the unselfish will to make the interest of the employe and of the community his own. But under our present social organization, even if one employer had all these, and could get foremen like unto himself, the selfishness of competitors, as well as that of the employes themselves, would force him out of business. He has to require preliminary knowledge in his employes, which means that this knowledge must be imparted by a teacher. He has to set an employe to doing something that the employe can do. There is but little time to teach the worker the significance of his task with respect to the rest of the establishment; still less of his place in the grand scheme of the universe. The foreman often has but little real teaching ability, even in the narrowest sense—the ability to impart the knowledge of his own immediate specialty; while he rarely has the opportunity, even if he had the ability, for the kind of teaching that would broaden the worker's vision, and so make

the worker's task something more than drudgery. All this, as well as the imparting of the necessary preliminary knowledge, is left to one who has some pedagogical ability, and who is therefore called a teacher.

And the teacher, even if he has this ability and Dewey's prophetic vision, still has charge of the pupil for only a small fraction of the year—say a thousand hours out of 8,760, if the pupil never misses any—for a few years; he has at best only a minute fraction of the knowledge that he ought to have in order to understand every pupil's needs and questions and abilities, and how to direct his activities so as to adapt him to his infinitely complex environment. He has only a fraction of the material equipment that he needs; in fact, he needs nothing less than the whole universe. An occasional excursion, with the pupils merely looking at things, does little if anything toward fulfilling this need. Each pupil, of course, needs to do actual work—cooking, running and repairing machines, etc. But this takes us back to the fact that employers and foremen do not in general want pupils or know what to do with them; while the teacher does not understand all these activities, nor could he be with all his pupils in them, even if he did.

I said that the teacher possesses only a minute fraction of the knowledge that he needs; and it is a smaller fraction today than it was fifty years ago, in spite of the rapid advances in teachers' qualifications; for the complexity of life, the sum of human knowledge, and the division of labor have advanced much faster, and will doubtless continue to do so, in spite of our most strenuous efforts to keep up. This is not a reason for giving up. On the contrary, it is precisely why we must increase our efforts. And no one can get a vision of this all-embracing ideal without seeing the folly of expecting it to be attained or even approached by the school teacher alone. Having charge of the pupil for a small fraction of the pupil's time, with a minute fraction of the necessary mental equipment, and an equally minute fraction of the material, the best to be hoped for in this way is the product of all these fractions; that is, less than the smallest of them. We cannot hope to gain on this fast-advancing ideal without the united efforts of all elements of society. The vision, and the thrill which it brings, must be shared not only by every teacher, but by every parent, every employer, and finally by every child. This requires that it be preached throughout all the world, not only to every teacher but to every creature. It is wholesome

to blame ourselves for every failure; doubtless we might have done better if we had known more and tried harder. But even a child is a human being, deserving credit or discredit according as he makes or fails to make proper choices and efforts. So I say that not only must teachers and others cooperate to unify the child's activities, so that study, work, and play shall not be three unrelated or conflicting universes; but the child himself must be given a better vision of his own duty, and be made to realize that after others have done all they can for him, he must still work out his own salvation.

MUST HELP RETURNING SOLDIERS.

The obvious first thing to do is to help the discharged soldiers to get work. To this end the United States Employment Service has taken steps to set up everywhere central Bureaus for Returning Soldiers and Sailors under the cooperating management in each community of all organizations ready to help. At each such bureau it is proposed to center all information as to positions available; to pool the opportunities, so that individual soldiers and every society, labor union, or other organization may utilize the whole field of community opportunities for work. Through its intercommunity and interstate clearance system and uniform records, the United States Employment Service can make surpluses of jobs in one place available for men applying where work is lacking.

Cooperating Agencies.

The whole national system of local councils of defense has undertaken to assist and supplement the work of 1,500 community labor boards set up as a war measure by the United States Employment Service in effecting such community cooperation. Promises of the assistance of such great national organizations as the Red Cross, the Y. M. C. A., National Catholic War Board, and the Jewish Welfare Board has been secured. Labor unions are cooperating. Churches, both English and foreign-speaking, are eager to help. The organization everywhere of such cooperating bureaus to help the soldier find a job is not only assured, it is already being rapidly effected. Their efficiency will be a question of local organizing capacity; a full measure of success in most places can hopefully be counted on.

Bureaus to Care for War Workers.

Such bureaus doubtless, too, will help care for returning civilian war workers, where the facilities of the United States Employment Service are not sufficient to meet the need. Many of these are as deserving, and perhaps will be more in need of help in finding work than the average returning soldier.

Furthermore, weekly information of a high degree of accuracy is being compiled by the United States Employment Service each week from over 100 industrial centers throughout the country as to local employment situations. Assurances have been received from the Army that it will be guided, so far as is possible, by this barometer in regulating the speed and distribution of military demobilization.

By and large the Employment Service and cooperating agencies are dealing, as it were, only with symptoms. They enable the man to find the open job with greater expedition. That is all. They don't create jobs.

OPTICAL GLASS MANUFACTURE IN AMERICA.

By L. M. Potter.

Secretary, Spencer Lens Company.

Few, indeed, appreciate the importance of optical glass as a factor in peace as well as in war. It was with the aid of optical glass in the form of microscopes that science has vanquished some of the greatest enemies of humanity; contagious diseases, parasitic fungi and insect destroyers of food plants and animals. With the development of modern artillery, and increased firing range, of ordnance in general, optical glass became an indispensable adjunct in military and naval warfare.

A field army or a battleship without optical equipment such as field glasses, telescopes, range finders, aiming circles, photographic lenses, etc., would be in the same serious disadvantage as a giant without eyesight.

The art of making optical glass has been until recently a closed book to the scientific world in general. Like in many other cases where a highly specialized industry has been developed upon empiric methods, the manufacture of optical glass has been shrouded in mystery.

An art born in France, it has been transplanted during the last century to England. Through the aid of a Swiss it came to Germany. With the development of artillery and the germ of world dominion lurking in the mind of the German Government, the importance of optical glass as an indispensable material for conducting modern war was realized there at a very early date. Fostered and encouraged by the German Government, a large industry developed. The advantages of a world monopoly were soon appreciated. For this purpose the processes, although carried on by the highest scientific authorities of the Empire, were kept secret. At the same time a lot of misleading, inaccurate information under the guise of scientific articles was published. The intricate methods and complex formulae "divulged" were intended only to becloud the matter. To discourage investigation and attempts of manufacture elsewhere, the material was sold to the world at relatively low prices, and in some instances even below cost. This deliberate attempt to establish monopoly, while not entirely successful, because certain quantities of optical glass have been manufactured in France and England, has, however, had the direct result of preventing the establishment of optical glass factories in the United States.

With the bursting of the war clouds in Europe, in the latter part of 1914, the sources of optical glass vanished as if by magic, as far as the American manufacturers were concerned. The demands for scientific apparatus increased constantly. The small stock of optical glass available was melting away at a disquieting rate, while the rumbling of the war became louder and louder. The situation was indeed critical. The frantic efforts to obtain European glass from France and England even by personal visits to these countries gave very discouraging results.

The Spencer Lens Company, pioneer microscope and optical instrument makers of America, in 1914, found themselves confronted with the fact that the stock of optical glass on hand was sufficient perhaps for only two years. A shut-down of their great plant seemed ultimately inevitable unless new sources of optical glass became available.

Urged on by such a necessity, this progressive company at once began experimental and research work leading to the manufacture of optical glass. Vast sums of money were expended in carrying on this great work.

About the same time the Bureau of Standards of the Department of Commerce in Washington began experiments with similar ends in view. A little later the Geophysical Laboratory of the Carnegie Institute

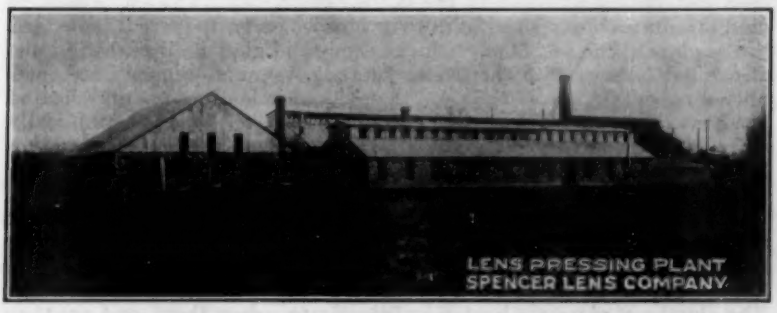
placed their large staff of scientists at the disposal of the United States Government and were assigned the task of aiding in the solution of what by that time had become known to be a very perplexing problem.

The generous manner in which this great group of scientists have devoted themselves to the task, the untiring efforts, the physical labor, the discomforts to which they have gladly subjected themselves in order to lay a scientific foundation for the making of optical glass, are beyond praise. A group of these scientists gave up their lifetime study and came to the factory of the Spencer Lens Company to cooperate with this company in devoting themselves to the new problems. One by one the difficulties (of which there were indeed many) were solved and fundamental laws and processes were established.

The development and growth of the enterprise soon necessitated expansion of facilities. This condition was immediately met by the Spencer Lens Company in the erection of new buildings and enlargement of those already built, until now the optical glass factory of the Spencer Lens Company, which was erected at Hamburg, New York, a suburb of Buffalo, away from the smoke, dirt and dust of a large city, is not only one of the largest but probably the most ideal and best equipped optical glass factories in the world today. The many types of optical glasses made in this great plant have been passed upon by experts and pronounced the equal of any made in the world; some types have claims of superiority. It is needless to say that the products of this factory played a very important part in the efficient equipment of the indispensable optical safeguards required by both Army and Navy of the United States during the past two years.

The great difficulty confronted in attempts at mass production have been many. Scarcity of high grade chemicals, potash especially, and the properly manufactured large clay crucibles of suitable quality have been important handicaps, but today all this has been surmounted and we can say without fear of contradiction that we are now producing optical glass in the United States of as good a quality and variety of types as has ever been imported from Europe.

The methods of production and required properties of optical glass differ considerably from the manufacture of any other type of glass. The finest window plate glass or French mirror glass and eye lens spectacles are very inferior materials when compared with optical glass needed in high grade observation and measuring instruments. Homogeneity in the mass of glass, as far as refractive index and dispersion are concerned, are ideals which probably are never fulfilled. In large blocks of optical glass it is quite frequent to note a difference in the sixth decimal point of the refractive index. Such minute and gradual variations are quite harmless for most optical purposes, but when similar defects come suddenly it is surprising to note how little it takes to make the glass useless for optical purposes. A limited number of fine bubbles or even opaque particles are, comparatively speaking, only minor defects, as they do not interfere essentially with the performance of optical instruments.



Optical glass must, besides, be free from strain. This arises from unequal contractions of outer and inner portions of the same piece of glass. Annealing is the process of very gradual cooling to overcome the tendency of strain. If glass is badly strained, besides being unfit for optical purposes it may fall to pieces during the process of manufacture. After all these conditions have been fulfilled, the main properties of optical glass, however, are definite points of refractive index and dispersion.

The actual process of manufacture may only be sketched briefly in a limited article of this sort.

The empty pot, as the large crucibles are called, having been gradually dried and heated to a bright red heat in a smaller furnace, called a pot arch, is taken hold of with a special apparatus called a "tong wagon" and placed in the previously heated larger melting furnace. The temperature of this is then gradually raised. When the predetermined temperature (about 200 F.) is reached, the "batch" mixture of chemicals is introduced in small quantities at a time. The pot is gradually filled with a molten mass, full of bubbles, however, derived partly from air enclosed by the particles of the raw materials and partly from the decomposition of the chemicals themselves.

Once the pot is filled, the temperature is further raised so as to liquefy the glass mass sufficiently to permit the bubbles to escape. This operation is called fining. The actual temperature varies with the different types of glass. Some glasses require temperatures that tax the furnace to its utmost. The action of the heat upon the crucible as well as the solubility of the crucible by the molten glass cause considerable risk, because they often lead to the breaking of the pot and complete loss of the glass. Great care and constant attention are essential. Frequent "proofs" (small test pieces) are dipped out from the pot by means of a

metal rod. When the samples show freedom from bubbles, the stirring process begins. The purpose of this operation is to make the glass as uniform as possible. This was a very laborious and extremely trying operation heretofore, as it begins when the glass has attained its maximum fluidity and maximum temperature. The workmen were alternated every few minutes and the iron bar fitting into the fire clay stirring tube changed at frequent intervals. This process has to be continued for about eight hours, until the glass is sufficiently cooled to become more and more viscous, until the stirring rod may be moved only by means of great effort. When the glass reaches this stage it is supposed that no settling will take place. We are using specially constructed electric driven stirring machines that not only do away with the hardship to the workman, but at the same time give a more steady and uniform agitation than is possible by hand. Again at a predetermined temperature, measured with optical pyrometers, the stirring is stopped. The clay cylinders used in agitating may be withdrawn or not; we prefer to leave it imbedded in the glass. The pot filled with the semi-solid glass is lifted bodily out of the hot furnace with the aid of the tong wagon aforementioned, permitted to cool for a brief time and then placed in another pot arch heated to about the same temperature as the pot itself. Here it is hermetically sealed and allowed to cool gradually to room temperature, an operation lasting about four days.

When the pot arch is opened the pot has usually a few decided cracks, and the mass of glass is fractured into a number of irregular pieces. The pot is now completely broken. The glass is subjected to a careful ocular inspection. A considerable part is rejected because of obvious defects. After "trimming" the glass into suitable pieces it is pressed into slabs. The chunks of glass are heated sufficiently to soften them, and are then shaped into squares with the aid of pneumatic presses. It is then carefully annealed, an operation again requiring about four days. These slabs, approximately 3-4 inch thick and 4x5 inches square, are by no means ready for use, but are now carefully ground and polished on the surface and subjected to a very rigid inspection in transmitted light with the aid of a specially designed optical apparatus consisting of two sets of achromatically corrected lenses giving parallel light. The finest "striae," as the defects of lack of homogeneity are called, become readily visible. After suitable marking, all defective parts are carefully cut and broken off. The remaining glass is now again passed through a third inspection. The narrow edges are strongly illuminated and the interior of the mass explored by the incident light against a black ground. All bubbles, feathers, stones and other minor defects become intensely illuminated, are marked out and cut or ground away, leaving the irregular pieces that, however, are quite free from any defects. It is only now that the product can be classed as optical glass. This glass is now ready to be again heated and pressed into the approximate shapes, discs, prisms, etc., into which they will finally find their way to the optical shops and turned into high grade optical lenses.

From the above it can be readily seen that the production of first grade optical glass is not simple, in fact it is an absolute precise scientific proposition. Approaching it on such a basis accounts for the phenomenal success which has been met with here in America in such a short time. It has been proclaimed by many authorities as one of the most successful and startling of the marvels of the war.

As a company we feel very proud of this contribution, which is only a part of that made by us, which we were able to make toward the winning of the war. Certainly the making of the materials which made

possible the very eyes of both Army and Navy is no small or unimportant part. We now have a factory for the manufacture of optical glass of sufficient size to provide the optical glass for nearly the whole world. We hope to have such cooperation and support from American scientists and manufacturers and from our Government as to make possible the future of this important American industry and thus to avoid the necessity in the future of depending on foreign sources of supply for such an important product.

ABSORBING VIBRATION.

There are certain branches of photographic work in which vibration may work havoc. The process worker adopts an elaborate series of precautions against it, and the photomicrographer and the copyist may both find it necessary to take steps to neutralize tremors if their work has to be done in a city or near a railway line. The motor 'bus has made such work impossible in some previously quiet city streets; and one photographer of our acquaintance has been compelled to resort to a swinging table for lantern slide making by reduction on this account. The means he has adopted may be worth mention for the guidance of others. A long work bench carries the camera and original in the usual way; but this bench, instead of being supported from beneath on four legs, is slung from above, by two loops of rope which pass around the ends of the bench and around a bar which is fixed from side to side of the room, parallel with the bench. The ropes are not mere continuous rings, but in each side have had inserted four strands of strong elastic rubber. These act as springs, and absorb any slight tremor, which otherwise might do mischief.—[*Photo-Era.*

The Geological Survey, Department of the Interior, has now available for distribution its annual statement on silver, copper, lead, and zinc in the Central States in 1917.

The annual statement of the United States Geological Survey, Department of the Interior, on the production of asphalt, related bitumens, and bituminous rock in 1917 is now available for distribution. The quantity of manufactured asphalt produced and sold in the United States in 1917 was 1,347,422 short tons, a gain of 86,701 tons, or about seven per cent, over the output in 1916. The quantity of natural asphalt, bituminous rock, and ozocerite produced and sold in 1917 was 80,904 short tons, a loss of 17,573 tons, or eighteen per cent less than the output in 1916.

NATURE AS SHE IS OBSERVED.

A nature-study and biology teacher somewhere in America sends to *The Nature Study Review*, the following casket of jewels culled from her pupils regarding their observations and conclusions in the domain of nature:

"Organic matter is when you have something the matter with your organs."

"Five devices by which seeds are scattered are wind, water, explosion, torn up, taken out, and thrown away."

"The peculiars of an insect are some of them bring diseases, others destroy food, suck the blood, spoil the flowers, lay eggs, and kill babies."

"The grasshopper, when he walks, he either jumps or hops."

"The jaws of a grasshopper move east and west."

"A larva is an unfinished animal."

"The flower is to show what a plant can do."

PROBLEM DEPARTMENT.

Conducted by J. O. Hassler,

Crane Technical High School and Junior College, Chicago.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and solve problems here proposed. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. If you have any suggestion to make, mail it to him. Address all communications to J. O. Hassler, 2337 W. 108th Place, Chicago.

Apology.

(Problem 574.)

The Editor apologizes for the carelessness in proof reading which allowed the words "from the vertex A" to be omitted from the statement of 574. This explains why no solutions were received. The editor in making up his published solution had the communication from the proposer with the original statement of the problem before him. The mistake is unpardonable and we will be glad to publish any solution sent in, the problem to be amended by adding at the end the four words "from the vertex A." The question in 591 should read, "How many of each kind did he buy?"

Query.

(Solution to problem 563.)

The question is raised as to whether all the statements in Philomathe's solution to 563 are justifiable by theorems of Book I as the proposed problem demands. One contributor would like to know why it is known that "XY is parallel to MF or BD." Will the solver please justify the statement?

Editor's Request.

Will Philomathe please make known to the Editor his real name and complete address? Problems may still be published under the name "Philomathe" but the Editor has desired to communicate with "Philomathe" more than once, and may again so desire.

SOLUTIONS TO PROBLEMS.

581. *Proposed by A. MacLeod, Aberdeen, Scotland.*

The six straight lines which trisect the angles of a triangle meet in three points which form the vertices of an equilateral triangle.

Could four equilateral triangles be found determined by the twelve interior intersection points of these six lines?—*Editor.*

No solutions received.—*Ed.*

582. *Proposed by A. MacLeod.*

A and B are two points outside a circle unequally distant from the center. Find the point C on the circle such that AC+CB is a minimum.

No solution by Elementary Geometry received. The following solution by means of conic sections is submitted by *Philomathe.—Ed.*

I. Let C be a point on the circle, such that $\angle ACB$ is bisected by the normal at C. Then AC+BC is a minimum, that is, for any other point C′ on the circle, we have AC′+BC′>AC+BC.

To prove it, draw the tangent at C, produce BC to A′, taking CA′ = CA, and join C′A, C′A′, C′B; also, let D be the intersection of C′A with the tangent, and join DB, DA′. We have AC′+BC′>A′C′+BC′>A′D+BD>A′C+BC or AC+BC.

$\therefore$ AC′+BC′>AC+BC.

II. How to locate point C.

Produce BC and AC, meeting the circle in M and N; draw tangents at

M and N, meeting tangent at C, in D and E respectively, then DC = CE. But the polar of B passes through D, and that of A passes through E. Hence, the question is to find a point C on the circle O such that the tangent at C, intersecting two given lines (XX′ and YY′) in D and E, gives DC = CE.

Let XX′ and YY′ be the axes of coordinates, and H the origin. Also let x', y' and α, β be the coordinates of C and O, respectively. If we draw HI parallel to DCE, the pencil H, DCEI is harmonic, since DC = CE. Hence, if

$$y-kx = 0 \tag{1}$$

is the equation of HC, that of HI will be

$$y+kx = 0. \tag{2}$$

The equation of OC is

$$y = \frac{y'-\beta}{x'-\alpha}x - \frac{y'-\beta}{x'-\alpha}\cdot\alpha+\beta. \tag{3}$$

As OC is perpendicular to HI, then, from (2) and (3)

$$1+\left(\frac{y'-\beta}{x'-\alpha}-k\right)\cos\theta-k\frac{y'-\beta}{x'-\alpha} = 0. \tag{4}$$

From (1) we derive

$$y'-kx' = 0. \tag{5}$$

Equating the values of k in (4) and (5), we get

$$y'^2-x'^2-y'(\beta+\alpha\cos\theta)+x'(\alpha+\beta\cos\theta) = 0.$$

Therefore, the point C (x', y') is on the curve

$$y^2-x^2-y(\beta+\alpha\cos\theta)+x(\alpha+\beta\cos\theta) = 0. \tag{6}$$

The point C belongs also to the circle

$$(x-\alpha)^2+(y-\beta)^2+2(x-\alpha)(y-\beta)\cos\theta-r^2 = 0. \tag{7}$$

But instead of solving the system (6), (7), which gives an equation of the 4th degree, it is preferable to find the intersection of the circle with the curve (6). This curve is an equilateral hyperbola, passing through H and O. Its center is $\frac{\alpha+\beta\cos\theta}{2}, \frac{\beta+\alpha\cos\theta}{2}$, and its asymptotes are parallel to the lines $y^2-x^2 = 0$, that is, to the bisectors of XX′ and YY′. So, the curve is easily constructed.

Rem. The circle and the hyperbola intersect in two points, which answer to a minimum and to a maximum in the value of AC+BC.

583. *Proposed by Norman Anning, France.*

Solve the triangle, $a = 181$, $A = 120°$, $b-c = 1$.

I. *Solution by William W. Johnson, Cleveland, Ohio.*

Using the law of sines, we obtain

$$\frac{b-c}{a} = \frac{\sin B-\sin C}{\sin A} = \frac{2\cos 1/2(B+C)\sin 1/2(B-C)}{2\sin 1/2A\cdot\cos 1/2A}.$$

But since $1/2(B+C)$ is the complement of $1/2A$,

$$\cos 1/2(B+C) = \sin 1/2A;$$

$$\therefore \frac{b-c}{a} = \frac{\sin 1/2(B-C)}{\cos 1/2A}.$$

Then,

$$\sin 1/2(B-C) = \frac{(b-c)\cos 1/2A}{a} = \frac{1}{362} = .00276243.$$

$1/2(B-C) = 0°9'29.8''$, and $1/2(B+C) = 30°$.

Adding and subtracting, we get

$\angle B = 30°9'29.8''$, and $\angle C = 29°50'30.2''$.

By the law of tangents, we have

$$b+c : b-c = \tan 1/2(B+C) : \tan 1/2(B-C).$$

Since $\sin 1/2(B-C) = 1/362$, then $\tan 1/2(B-C) = 1/209\sqrt{3}$. Whence,

$$b+c = \frac{\cot 1/2A}{\tan 1/2(B-C)} = \frac{\sqrt{3}/3}{1/209\sqrt{3}} = 209.$$

Since $b+c = 209$ and $b-c = 1$, we find $b = 105$ and $c = 104$.

II. Solution by E. D. Searls, New Bedford, Mass.

$$\begin{aligned} a^2 &= b^2+c^2-2bc\cos A \\ 181^2 &= b^2+c^2-2bc\cos 120° \\ \cos 120° &= -1/2 \\ \therefore b^2+bc+c^2 &= 32761 \\ b^2-2bc+c^2 &= 1 \\ 3bc &= 32760 \\ bc &= 10920 \\ b^2+2bc+c^2 &= 43681 \\ b+c &= 209 \\ b-c &= 1 \\ b &= 105 \\ c &= 104 \end{aligned}$$

The angles are computed by Law of Sines with results as in Solution I. Omitted to save space.—*Ed.*

Also solved by C. E. Githens, Murray J. Leventhal, R. M. Mathews, S. H. Parsons *and* Philomathe.

584. *Proposed by Norman Anning.*

AD, BE and CF are the medians of the triangle ABC; show that $\cot ADB+\cot BEC+\cot CFA = 0$.

I. *Solution by Philomathe, Montreal, Can.*

From A, draw AH $\perp$ to BC.

We know, from Geometry, that $\overline{DH} = 1/2(\overline{CH}-\overline{HB})$, (DH being positive, null, or negative, for ADB $<$, $=$ or $>90°$)

$$\cot ADB = \frac{DH}{AH} = \frac{1}{2}\left(\frac{CH}{AH}-\frac{HB}{AH}\right) = 1/2(\cot C-\cot B),$$

In the same way, $\cot BEC = 1/2(\cot A-\cot C)$,
and $\cot CFA = 1/2(\cot B-\cot A)$.

$$\therefore \cot ADB+\cot BEC+\cot CFA = 1/2(\cot C-\cot B)+1/2(\cot A-\cot C)+1/2(\cot B-\cot A) = 0$$

II. *Solution by R. M. Mathews, Duluth, Minn.*

The altitude from A is equal to $b\sin C$. The distance from D to the foot of this altitude is equal to $(b\cos C-1/2a)$ and is positive or negative according as the segment lies from D toward B or toward C. Thus we have both in sign and magnitude

$$\cot ADB = \frac{2b\cdot\cos C-a}{2b\sin C}.$$

Similar relations follow for the other angles, and

$$\cot ADB+\cot BEC+\cot CFA = \frac{2b\cdot\cos C-a}{2b\sin C}+\frac{2c\cdot\cos A-b}{2c\sin A}+\frac{2a\cdot\cos B-C}{2a\sin B}$$

For $\cos C$ substitute $\frac{a^2+b^2-c^2}{2ab}$ and for $2\sin C$ put c/R, where R is the radius of the circumscribed circle. The first fraction reduces to $R/abc(b^2-c^2)$. The other fractions reduce by similar substitutions and the sum of the three is evidently zero.

Also solved by MURRAY J. LEVENTHAL.

585. *Proposed by Norman Anning.*

Eliminate θ from the equations

$$x = \cos 2\theta + 2\cos\theta,$$
$$y = \sin 2\theta - 2\sin\theta.$$

Solution by Philomathe, Montreal, Can.

Given $x = \cos 2\theta + 2\cos\theta$ (1)

$y = \sin 2\theta - 2\sin\theta$ (2)

From (1) we derive $2\cos^2\theta + 2\cos\theta = 1 + x$; hence, $\cos\theta = \dfrac{\pm\sqrt{3+2x}-1}{2}$;

Squaring (1) and (2), and adding, we get $x^2+y^2 = 5+4\cos 3\theta$; hence $\cos 3\theta = \dfrac{x^2+y^2-5}{4}$.

But $\cos 3\theta = 4\cos^3\theta - 3\cos\theta$.

Therefore, $\dfrac{x^2+y^2-5}{4} = 4\left(\dfrac{\pm\sqrt{3+2x}-1}{2}\right)^3 - 3\left(\dfrac{\pm\sqrt{3+2x}-1}{2}\right)$

or, after simplifying, $x^2+y^2+12x+9 = \pm 2(3+2x)^{3/2}$.

Also solved by R. M. MATHEWS, E. D. SEARLS, WALTER R. WARNE *and the* PROPOSER.

PROBLEMS FOR SOLUTION.

The Editor has had proposed for this department by different contributors three problems in the chain leading up to the famous "Problem of Apollonius." He has concluded that a series of five problems, the first being No. 598 (in this issue) and the fifth to be the "Problem of Apollonius" (June issue) would have educative value and would doubtless furnish to many of our readers new material for consideration. Perhaps some new methods of solution will be discovered.

Algebra.

596. *Proposed by Walter R. Warne, Dickinson College, Carlisle, Pa.*

Solve, $x^4 - 2x^3 + x = a$.

597. *Proposed by R. T. McGregor, Elk Grove, Cal.*

Show that $n^7 - 7n^5 + 14n^3 - 8n$ is a multiple of 840 if n is an integer greater than 2.

Geometry.

598. *Proposed by the Editor.*

Describe a circle through two given points tangent to a given circle.

599. *Proposed by Walter R. Warne.*

If A, B, C, D be any four points on a circle and O any fifth point taken arbitrarily, and if we denote by BCD the area of the triangle BCD, etc., then

$$OA^2 \cdot BCD + OC^2 \cdot ABD = OB^2 \cdot ACD + OD^2 \cdot ABC.$$

Trigonometry.

600. *Proposed by Walter R. Warne.*

Eliminate θ from the equations,

$$x = a(\sin 3\theta - \sin\theta)$$
$$y = a(\cos\theta - \cos 3\theta).$$

SCIENCE QUESTIONS.

Conducted by FRANKLIN T. JONES,
The Warner and Swasey Co., Cleveland, Ohio.

Readers are invited to propose questions for solution—scientific or pedagogical—and to answer questions proposed by others or by themselves. Kindly address all communications to Franklin T. Jones, 10109 Wilbur Ave., Cleveland, Ohio.

Please send examination papers on any subject or from any source to the Editor of this department. *He will reciprocate by sending you such collections of questions as may interest you and be at his disposal.*

Send Your First Term Examination Papers Now.

State Board Questions

Examination questions are desired from the state examinations of Wisconsin, Michigan, Illinois, Indiana, Nebraska, Iowa, and Kentucky, as well as from other states giving examinations.

Tests in Chemistry.

Please note our request in the January issue asking cooperation on chemistry tests. The following have asked for tests on chemistry (please note that the ten contributors asked for in January Science Questions, are exclusive of those mentioned below).

Norman P. Bish, Westinghouse High, Pittsburgh, Pa.; Wm. Breitwieser, Allegheny High School, Pittsburgh; E. R. Carson, Munhall, Pa.; Chas. C. Dunning and C. A. Gorgas, Peabody H. S., Pittsburgh; Chas. H. Korns, South H. S., Pittsburgh; F. G. Masters, Fifth Ave., H. S., Pittsburgh; Jas. W. Mates, Wilkinsburg, Pa.; D. E. Miller, Schenley H. S., Pittsburgh; J. Gordon Ogden, Fifth Ave. H. S., Pittsburgh; David B. Righ, Schenley H. S., Pittsburgh; J. A. Timlin, South Hills H. S., Pittsburgh; and J. A. E. Zimmerman, Homestead, Pa.

Tests in Physics.

The interruption of schools due to influenza and unsettled conditions has seriously interfered with progress in tests on physics. Return to normal conditions encourages a recommencement of the standardization of the physics tests already partially described in *The School Review*, May, 1918.

The following teachers from Pittsburgh and vicinity have expressed their interest in these tests. Similar community groups might work together in such a movement with great interest and professional profit. Why not?

E. R. Carson, Munhall, Pa.; Chas. C. Dunning, Peabody H. S.; P. M. Dysart, Schenley H. S.; L. C. French, Ambridge, Pa.; Chas. H. Korns, South H. S.; Jas. W. Mates, Wilkinsburg; J. Gordon Ogden; Fifth Ave. H. S.; Hugh L. Porter, Allegheny H. S.; Helen A. Strouse, Greensburg; J. A. E. Zimmermann, Homestead.

QUESTIONS AND PROBLEMS FOR SOLUTION.

314. Are teachers and pupils satisfied with the questions asked on college entrance examinations in physics, especially Board examinations? Here is your chance to offer suggestions.

"Is there anything to be said about the comprehensive physics, or chemistry, papers of the College Entrance Board? In the absence of any criticisms or suggestions from teachers in active service, the Board will be justisfied in considering that the papers are satisfactory. Speak up, gentlemen. [Signed] John C. Packard, Brookline, Mass., member of Committee on Revision."

In answer to the above, propose questions, or a series of questions, such as the Board **ought** to use.

SOLUTIONS AND ANSWERS.

Further discussion is desired.

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310. What questions on science, new and old, has the war brought to our attention?

Discussion by A. Haven Smith, Riverside, Cal.

Enclosed you will find a set of examination questions given recently at the Naval Academy, Annapolis. They are extremely interesting because of the source from which they come and the time at which they were given. They emphasize the fundamentals of the subject but otherwise there is little in them to show that this class was being pushed to the limit in preparation for an active part in the great war.

DEPARTMENT OF ELECTRICAL ENGINEERING AND PHYSICS.

Monthly Examination, Second Month, Third Class, November, 1918.

November 12, 1918, 8 *a. m. Time allowed* 2 *hours.*

Enter at the end of your examination paper the time of finishing the examination.

1. (a) State under what conditions (1) a siphon, (2) a suction pump, and (3) a force pump could be used to obtain water from a well on a hillside. (b) A change of one inch in the barometer reading produces what change in the height a water column stands and in the pressure per square inch?

2. (a) How many jack screws each having three threads to the inch and operated by handles 14 inches long are required to raise a building weighing one hundred tons (1 ton equals 2,000 pounds), assuming the efficiency of a jack to be 35 per cent and that a man can apply an effective force of 200 pounds to the handles? (b) A wheelbarrow having handles 4 feet long has the center of gravity of the load 18 inches from the axle of the wheel. What weight can be supported on the wheelbarrow by a force of 500 pounds applied at the end of the handles? What class lever is the wheelbarrow?

3. Distinguish between density and specific gravity and describe briefly one method for determining each. What is meant by saying a body has a density of 3.5? Of 0.525? A specific gravity of .8?

4. Describe one method for the accurate determination of the velocity of sound waves, stating what corrections are necessary.

5. (a) Determine the pitch of the note emitted by an iron wire 60 cm. long weighing 2 gm. under a tension of 20 kgm. (b) To double the pitch of the same wire, what must the length be made, tension remaining constant?

6. (a) State the characteristics of musical sounds and on what each depends. (b) What are the relations of open and closed pipes in respect to (1) the position of nodes and antinodes, (2) the length of pipe to give the same pitch, (3) the relation of overtones to fundamentals?

7. Determine the specific gravity of a piece of brass weighing 50 gms. in air and 44 gms. in water. What is the volume of the brass and what will it weigh in a liquid of specific gravity 1.20? What is the density of brass in the Metric and English units?

8. State the Principle of Archimedes and show how it applies to buoyancy in air. Explain how and why the regulation of the height of a balloon is affected.

REMOVING HYPO FROM NEGATIVES.

Some workers waste a lot of gray matter over washing negatives to remove the hypo, when the thing is simplicity itself. Use plenty of fresh water—that is all. Less hypo in the film is eliminated when the negatives remain stationary than when they are in motion. When the plates are soaked in frequent changes of fresh water, virtually all the hypo in the film is removed in twenty minutes; if the plates and water are kept in motion, ten minutes will suffice. Hence, it is useless to rinse the negatives more than twenty minutes, particularly in warm weather, when prolonged washing has a tendency to soften the film.—[*Photo-Era.*

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ARTICLES IN CURRENT PERIODICALS.

Americans Journal of Botany, for December; *Brooklyn Botanic Gardens*; $5.00 *per year*, 60 *cents a copy:* "Endurance of Extreme Conditions and Its Relation to the Theory of Adaptation," W. J. V. Osterhout; "A Simple Method of Demonstrating the Production of Aldehyde by Chlorophyll and by Aniline Dyes in the Presence of Sunlight," W. J. V. Osterhout; "Oreomyrrhis Borneensis Merr. sp. nov., an Interesting Addition to Our Knowledge of the Malayan Flora," E. D. Merrill; "Root Absorption from Solutions at Minimum Concentrations," R. B. Harvey and R. H. True; "Uredinales of Guatemala Based on Collections of E. W. D. Holway. IV. Puccinia on Carduaceae, Form-genera and Index," J. C. Arthur.

Bird-Lore, for November-December; *Harrisburg, Pa.*; $1.50 *per year:* "Notes from a Traveler in the Tropics. Down the Coastline to Cuba," Frank M. Chapman; "When the North Wind Blows," A. A. Allen; "Homeland and the Birds," Mabel O. Wright; "A Wild Duck Trap," Verdi Burtch.

Botanical Gazette, for December; *The University of Chicago Press*; $7.00 *per year*, 75 *cents a copy*; "Limiting Factors in Relation to Specific Ranges of Tolerance of Forest Trees," A. H. Hutchinson; "Notes on North American Trees," C. S. Sargent; "The Purple Hyacinth Bean," George F. Freeman; "A Morphological Study of Pallavicinia Lyellii," Arthur W. Haupt.

Journal of Geography, for December; *Broadway at 156th St., New York City*; $1.00 *per year*, 15 *cents a copy*: Agriculture in China," Ira C. Davis; "A Short Bibliography of U. S. Climatology," R. De C. Ward; "Salt Lake City and Its Geographical Setting (Map)," Jehiel S. Davis; "Ohio Canals (Map)," Charles K. Chapman; "Calcutta," Albertine Metzner.

Journal of Physical Chemistry, for November; *Ithaca, N. Y.*; $4.00 *per year;* Methane Williams Molisoff and Gustav Egloff: "Crystalloluminescence," Harry B. Weiser.

National Geographic Magazine, for October; *National Geographic Society, Washington, D. C.;* $2.50 *per year*: "Russia's Orphan Races," 27 illustrations, Maynard O. Williams; "What the War Has Done for Britain," 13 illustrations, Judson C. Welliver; "How Canada Went to the Front," 6 illustrations, T. B. Macaulay.

Nature-Study Review, for December; *Ithaca, New York;* $1.00 *per year*, 15 *cents a copy*: "The Moon Story," Ethel H. Hausman; "The Moon, A Physical Geography Lesson," Lena S. Thomas; "First Grade Readers, A Survey and Criticism," William G. Vinol; "The Beginning of Star Study," Anna B. Comstock.

Photo-Era, for December; 367 *Boylston Street, Boston, Mass.,;* $2.00 *per year*, 20 *cents a copy*: "Niepce and Daguerre (Third of the 'Professor Pyro' Talks)," Michael Gross; "The Reticulation of Gelatine," S. E. Sheppard and F. A. Elliott; "Pictorial Printing," H. A. Brodine; "In Elfland with a Camera," Edward Lee Harrison; "Photographic Preparedness," Winn W. Davidson.

Popular Astronomy, for January; *Northfield, Minn.*; $3.50 *per year:* "The Naval Observatory Eclipse Expedition, June 8, 1918, Novae," Vincent Francis; "The Influence of Astronomy on Human Thought," Rev. Hector Macpherson; "Astronomical Phenomena in 1919,"

Physical Review, for December; *Ithaca, N. Y.*; $6.00 *per year*, 60 *cents a copy:* "Latent Heat of Fusion as the Energy of Molecular Rotations," Kotaro Honda; "The Physical Characteristics of X-Ray Fluorescent Intensifying Screens," Millard B. Hodgson; "The Specific Heat of Platinum at High Temperatures," Walter P. White; "The Photographic Study of Impact at Minimal Velocities," C. V. Raman; "Gases and Vapors from Glass," R. G. Sherwood; "The Electromagnetic Vectors," H. Bateman; "Ionization of Mercury, Sodium and Potassium Vapors and the Production of Low Voltage Arcs in these Vapors," T. C. Hebb.

Sugar, for December; *Edison Building, New York City*; $2.00 *per year*: "Beet Sugar Factories," Frank Coxon; "Better Results by Better Management," L. W. Alnyn Schmidt; "The Future Sugar Industry in Siam," Lewis Swarl; "Valuation of Raw Sugars," W. D. Home; "New Beet Harvesters," H. P. Twendly.

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Teachers College Record, for November; *Bureau of Publications, Columbia University, New York City*; $1.50 *per year*, 40 *cents a copy*. "The Place of Duty and Discipline in a Democratic Scheme of Education," William C. Bagley; "The Secret of Thrift: a New Aladdin's Lamp for Every Boy and Girl," Clifford B. Upton; "Health Exercises for Everyday Use," Jesse F. Williams.

BOOKS RECEIVED.

American Red Cross Textbooks.

Home Hygiene and Care of the Sick, by Jane A. DeLano, R. N., chairman National Committee, Red Cross Nursing Service, and Anne H. Strong, R. N., Simmons College. Pages xv+334. 12×18 cms. Paper. 1918. 50 cents.

First Aid, General Edition, by Colonel Charles Lynch, U. S. Army. Pages xiv+209. 12×18 cms. Paper. 1918. 35 cents.

First Aid, Woman's Edition, by Colonel Charles Lynch. Pages x+194. 12×18 cm. Paper. 1918. 35 cents. P. Blakiston's Son & Co., Philadelphia.

Stories of Americans in the World War, by William H. Allen, Director Institute for Public Service. 176 pages. 13.5×18.5 cm. Paper. 1918. 30 cents. Institute for Public Service, 51 Chambers St., New York City.

Handbook of Physics Measurements, by Ervin S. Ferry, Perdue University. Vol. 1, Fundamental Measurements, Properties of Matter and Optics. Pages ix+251. 14×20.5 cm. Cloth. 1918. $2.00 net. Vol. 2, Vibratory motion, Sound, Heat, Electricity and Magnetism. Pages x+233. 14×20.5 cm. Cloth. 1918. $2.00 net. John Wiley and Sons, New York City.

The Beginnings of Science, by Edward J. Mengl, University of Dallas. 256 pages. 14×20 cm. Cloth. 1918. $2.00 net.

Backgrounds for Social Workers, by Edward J. Mengl. Pages 214. 14×20 cm. Cloth. 1918. $1.50 net. Richard G. Badger, the Gorham Press, Boston, Mass.

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